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ABSTRACT

This review presents a broad perspective of the state of knowledge in science education, a description of existing trends, the areas where research is needed, and tentative answers to persistent problems that have been identified from the research. The review is organized into eight sections. An introductory section describes methods of using research to understand the science learning context. Five following sections focus on research dealing with the elementary school student, the emerging adolescent, the adolescent, the undergraduate college student, and the science teacher. The last two sections deal with measurement instruments used in science education, and an historical perspective relating science education research of 1979 to that of the past and discussing trends and implications for future research. (CS)

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A SUMMARY OF RESEARCH
IN
SCIENCE EDUCATION--1979

David P. Butts

Department of Science Education
University of Georgia
Athens, Georgia 30602

National Association for Research in Science Teaching

and

ERIC Clearinghouse for Science, Mathematics,
and Environmental Education
The Ohio State University
1200 Chambers Road
Columbus, Ohio 43212

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U.S. DEPARTMENT OF HEALTH,
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Preface

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a one year period of time. These reviews are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Readers' comments and suggestions for the series are invited.

Stanley L. Helgeson
Patricia E. Blosser
ERIC/SMEAC

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION—1979

David P. Butts
University of Georgia
Athens, Georgia 30602

USING RESEARCH TO UNDERSTAND THE SCIENCE LEARNING CONTEXT

A Search for an Order of Ideas

Research in science education is the search for relevant variables by which we can both understand and nurture scientific literacy. In this search, the reality of the science learning context may be made to fit our conceptualization of that context. Or, it is possible that our ideas about the science learning context are based on what is found in that context. Brunswik (1952) aptly described the second possibility as the desired one, "Let the order of ideas, be the order of things." But what is the order of things? What occurs when students learn science or become scientifically literate?

When a learning environment and, in the case of this research review, the science learning environment is reflected upon, its order seems to depict three components. There are the personal interactions among teacher and students. These interactions are part of an instructional interaction that includes both the content and the methodologies used. The amount and source of the control of both the personal and instruction interactions are shared in varying degrees by the teacher and the students. Surrounding these interactions are the expectations of schools as they reflect what society in general expects these institutions to accomplish.

Learning in science is thus influenced by both the instructional interactions and those in other areas of the schooling experience as well as by the home, community and broader social pressures. Figure 1 illustrates how "the order of things" includes what is happening in a science learning context as part of a much larger environment. It is in the total environment that many cues are available to help us understand and nurture the science learning context.

Basic to the "order of ideas" about the "order of things" is the assumption that cues in an environment must be perceived and that judgmental responses must be made to them. In addition, what we do, our responses, are in part shaped by what we perceive to be the consequences of that action (Woodruff, 1968). Our research can help us have a richer perception of cues from our science learning contexts--and it can help us make wiser responses to our new knowledge. Hammond (1966) described a rationale for this.

> In order for the organism to perceive correctly (i.e., to achieve) the intended object, the organism must have information about it. Information is provided by the stimulation at the proximal layer; a stimulus in this region is referred to as a sensory _cue_. Such cues are the physical stimuli impinging on the surface of the organism, but they are more than that. They are the _local signs_ that have a reference in the world of objects. Put otherwise, proximal stimuli are _local representatives_ of distal objects or distal variables (p. 26).

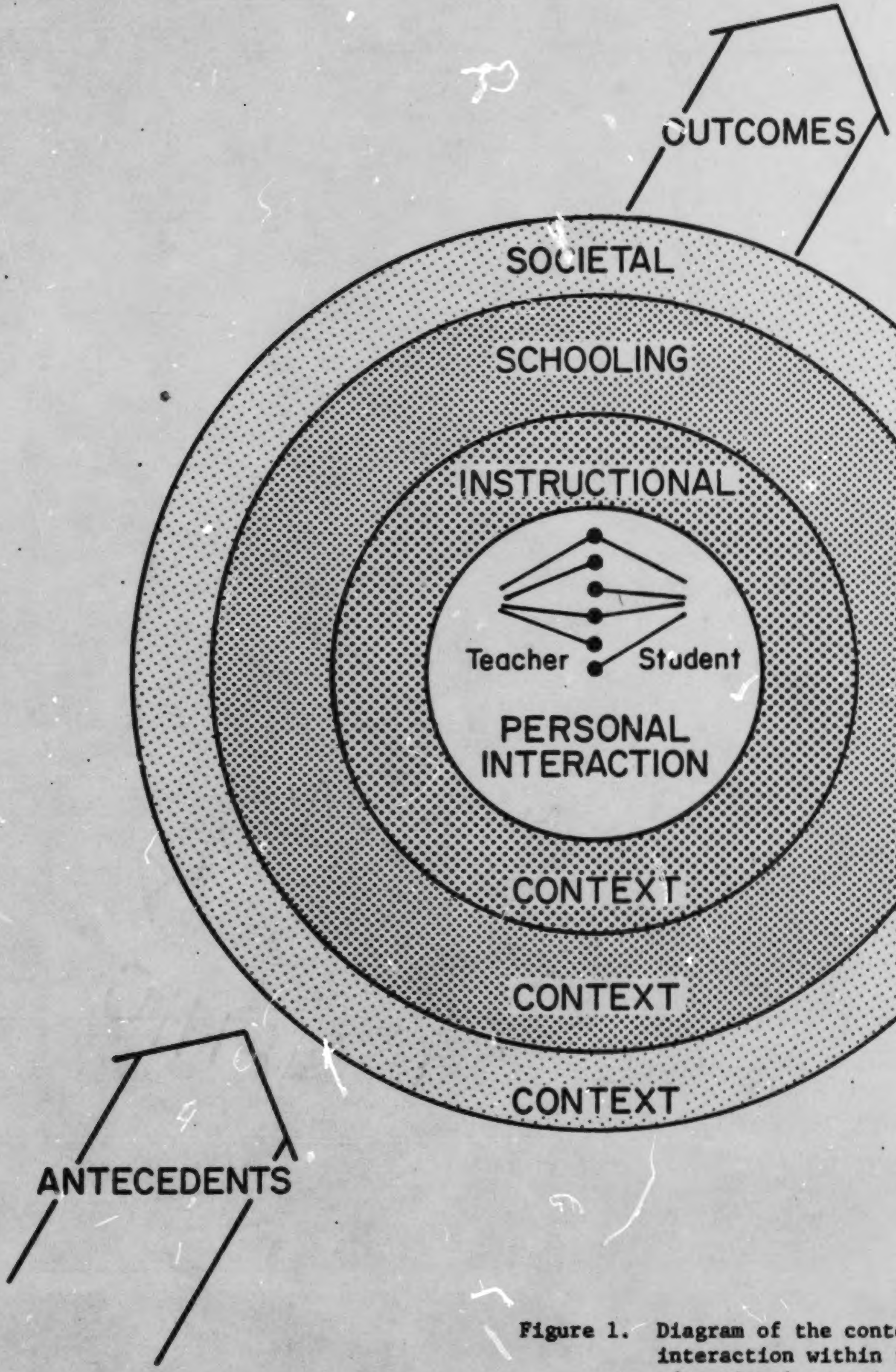

Figure 1. Diagram of the contexts for interaction within the educational experience.

Tolman and Brunswik (1935), describing this situation, stated:

> By means of such local representatives the organism comes to operate in the presence of the local representative in a manner more or less appropriate to the fact of a more distant object or situation, that is, the entity represented. (p. 43)

Hammond (1966) continues:

> The proximal stimulus then is a local representative that provides only a "hint" in an uncertain situation as to the nature of the object. Not only must the organism have information in order to achieve a distal object, it must have a means for achieving its goals. (p. 26)

The Order of Ideas in Research in Science Education

To describe research in science teaching is to assume that one has an operational picture of this subject. In the ancient's day this assumption was well described by the story of the six blind men of Industan as each one in his own way was carefully describing the subject of his attention. Each was sure his description was precise and accurate. From today's vantage point, it is evident that the author of this fable was correct in that each of the six men failed to grasp the complete dimensions of their search. But what about the arrogance of the author of that fable in assuming that he could, indeed, see the complete picture?

To describe research in science teaching does seem to imply that we can stand high enough on the shoulders of colleagues to be able to view the domain encompassed by the subject. Is our order of ideas governed by the order of things? Which research studies should be considered the benchmarks of research in science teaching? Suppose one were to list the 21 research studies considered to be the most important in science teaching. Which would be selected? A more relevant question would be--by what criteria would they be selected?

In a volume describing research during 1948-52 (Swift, 1969), the criterion for selection was the number of times the research study was quoted in other research studies. While that criterion may not be adequate, what better one could be used? Ebel (1967), for example, suggests that the relevance of research to practice is an appropriate criterion. Lamke (1955) suggested that

> If the research in the previous three years of medicine, agriculture, physics, and chemistry were to be wiped out, our life would be changed materially. But if research in the area of teacher personnel in the same three years were to vanish, educators and education would continue much as usual. (p. 192)

In what way is research in science education relevant to practice? Is it relevant to teaching? Gage (1968) emphasizes that the need in educational research is precisely the teacher's behavior. Gage states that

> It is all right for a teacher to know about learning, to know her subject matter, to have appropriate instructional material, and to fit into a given organization for instruction. But what a teacher really wants to know is "What should I do in the classroom?" (p. 119)

On this one dimension, what does the research in science education have to say to a teacher at any level: elementary, junior high, high school, college or teacher educator?

Research on science teaching and learning represents two clearly defined tasks. One is research on learning which Gage (1968) defines as dealing with those conditions under which learning or change in behavior due to experience occurs. Research on teaching, however, includes the conditions under which learning occurs in one person--or the conditions established by the behaviors of another person. Is the teacher a helpful assistance or a hindrance to learning? Indeed, is experience necessary for learning? The contrasts between teaching and learning are further illustrated in a recent statement by Piaget (1970). When asked about what specific points of his work were most relevant to educational changes, Piaget (1970) stated

> In my view, our most decisive finding is that knowing in its various manifestations does not uniquely derive from external world through mere perceptual experiences, or through social transmission, but supposes a construction activity on the part of the subject. However, one should not assume that knowing is written into a subject from his beginning as innately given and a priori. Rather, it implies that each developmental stage and for each new problem some aspect of real construction. This I can see above all the problems for the school. What in fact should be its goal? Is it to produce individuals who can repeat what is known already and who can register and accumulate in their memory the sum of the already acquired knowledges, or rather should the goal of education be to produce a person who is in differing degrees or at least within the domain of his chosen activity (if not on all domains) capable of creating and discovering new things, an individual who can contribute something new to the knowledge of previous generations? For my part, I would think that if one succeeds in developing the creative mind of an individual, he will have all his life to consult libraries and learn all the acquired knowledges. Whereas, if one limits oneself to shaping individuals who only repeat what they have learned, they will never know how to discover new solutions. The aim of education above all is to foster a creative mind in the thinking and doing of the

> child and consequently to emphasize as much as possible individual initiative.
>
> Individual initiative does not mean that the child can do what he pleases. It implies some material prerequisites in challenging situations that pose problems to the child's mind that orient him in certain research directions. At the same time the teacher must be content to stimulate and lead the child in appropriate direction without giving solutions to him from the beginning. The teacher must give the child the opportunity to rediscover as much as possible instead of merely learning from external authority. In this manner, the child will grow into an adult who in real life is capable of finding new solutions. (p. 1)

For the learning psychologist, further studies on learning are both needed and important. The science education researcher should use all available assistance in providing instructional strategies with an empirical base to aid a teacher in deciding which instructional strategy to use when and for which students. We have the question, "What should I do in my classroom?" How can this question be approached? Gage (1968), Medley (1979), and Rosenshine (1979) have suggested that much effort has been expended in rather fruitless studies to identify the effective teacher. The results of the search for this elusive concept have served to convince many scholars and researchers that, rather than global concept of effective teaching, one should empirically establish small or micro criteria for effective teaching. A strategy for doing this has been identified by Gagne (1967) when he said that he still is not ready to repudiate his assertion made ten years ago that the best source of experimental problems in the study of problem solving is an examination of people solving problems. By extrapolation then, the best source for studying teaching is to study people teaching.

Knowing how to teach appears to be a similar way to express the question "What should I do?" Is there a single way to do it? As described by Medley (1979), this is a search for the best method of teaching. Analysis of classroom behavior is not a new subject of interest to researchers. A number of systems (Ryans, 1963; Jackson, 1966a; Cronbach, 1967; Biddle, 1964; Carroll, 1965; Siegel and Siegel, 1967; Flanders, 1964; Meux and Smith, 1964) have been generated as ways to describe classroom behavior. In many ways these same category systems have been used to assist teachers in acquiring new strategies of instruction. Faced with this plethora of systems, which is the best?

The answer to this question will essentially be embedded in one's assumption about teaching. Analysis of people teaching can be made based on two contrasting assumptions about teaching. The macro view suggests that teaching is an art and that it can best be emulated by modeling the master teacher. The micro view of teaching suggests that teaching is an act, which can be subjected to systematic analysis and emulated by mastering the model teacher's component behaviors.

Within the last set, one can identify a set of dependent variables or performances of a teacher such as "establishing set" or "establishing appropriate reference" or "achieving closure" or "using questions" or "recognizing an attending behavior" or "control of participation" or "providing feedback" or "employing rewards and punishments" and "setting a model." To study the role of these skills in teaching, other sets of independent variables such as practice variables, feedback variables, and demonstration variables can be set up and studies conducted. An alternative to this approach has been described by Jackson (1966b) when he said

> Individualizing instruction in the educator's sense means injecting humor into a lesson when a student seems to need it, and becoming serious when he is ready to settle down to work. It means thinking of examples that are uniquely relevant to the student's previous experience and offering them at just the right time. It means feeling concern over whether or not a student is progressing and communicating that concern in a way that will be helpful. It means offering appropriate praise not just because positive reinforcers strengthen response tendencies, but because the student's performance is deserving of human admiration. It means in short responding as an individual to an individual. (p. 1)

Although micro teaching seems to be based on the assumption that teaching is the imparting of information, a more macro view adds the dimension of the teacher as an individual responding to other individuals.

Thus the question, "What should I do in the classroom?" further emphasizes that it is true that two essentials of a good teacher are a) enthusiasm, and b) thorough interest in his subject. A third essential is knowing how to teach.

In addition to deciding which system to use based on one's view of teaching, a second set of variables should be considered. Individual differences in students have long been recognized, researched, reported, and remediated. Similar differences are likely to be found in teaching styles. Can one support a set of categories supposed to be common to all teachers at all times in all situations? Is it possible that there are identifiable teaching styles which produce equally healthy student achievement but which differ markedly in their approach to similar science teaching challenges? Are some of these categories of analysis of teachers appropriate to some teaching styles but not to others? What empirical evidence do we have to suggest to a teacher who demonstrates an identifiable teaching style that, in order to produce healthy student achievement, he/she needs to acquire the entire repertoire of individual teaching strategies which can be taught?

In searching among the order of things to find an order of ideas, the target of research has shifted from the listing of essential characteristics of teachers that might make a difference in student outcomes to contrasting instructional approaches, to process/product descriptions in which what a teacher does has an impact on the classroom climate and ultimately on how much students learn. Thus, research in science education may focus on the instruction filter, the teacher filter, the student filter--or their interaction (Figure 2).

As reflected in the science education research in 1979, we have a wide variety of cues--a rich source of information about the "order of things" on which to build our "order of ideas." In this research we have cues about the immediate science learning contexts and, to some extent, some potential insights about the school and about social influences on science learnings of students.

Schooling may be viewed as a continuous context from preschool to graduate school. Within the schooling/society context, it is helpful to organize information as it fits the conventional organization of schooling--the learning context of elementary schools, of middle/junior high schools, of high schools, of undergraduate colleges.

In science education research, a fifth context is observed--the professional development of science teachers. Within each of these instructional or learning contexts, the "order of things," or cues, seem to fit from three "order of ideas"--cues related to the students, the teachers, and the instruction (Figure 3). These three primary sources of cues do not exist in isolation. They may be viewed as filters through which the intended outcomes of schooling are translated into the actual achievements or outcomes. The interaction or influence of each filter with the intended outcome is not a simple $a + b = c$ paradigm, however. Rarely is there such an overwhelming student characteristic (b) which when added to instructional goals (a) will always produce results in achievement or outcomes (c). Rather, each of the three filters (students b^1, teacher b^2, instructional b^3) are interacting together as $a(b^1 \times b^2 \times b^3) = c$.

Looking back on the science education research of 1979, it is possible to see patterns of the "order of things" which enrich our understanding of our "order of ideas."

> We can know more about students and their characteristics which appear to influence the interactions of the learning context and the outcomes of science learning.
>
> We can know more about teachers and their characteristics which appear to influence their interactions with students in the learning context of science.
>
> We can know more about instruction, that is, specific science content, specific instructional strategies and how they are related to science learning contexts and instructional outcomes.

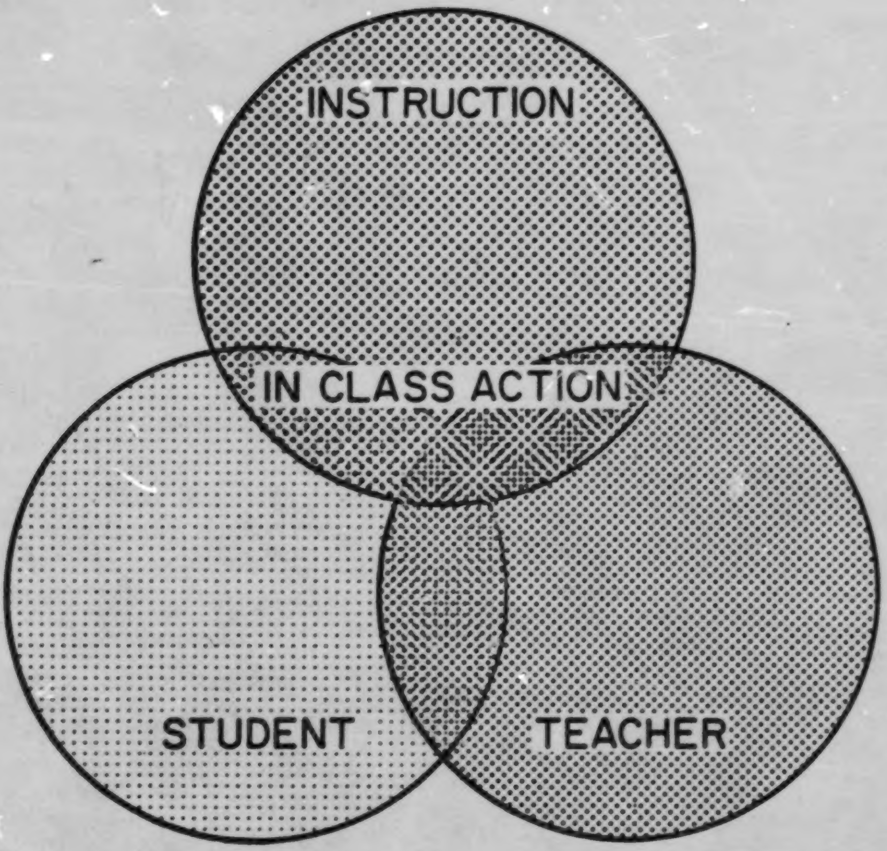

Figure 2. The three filters in the science learning context.

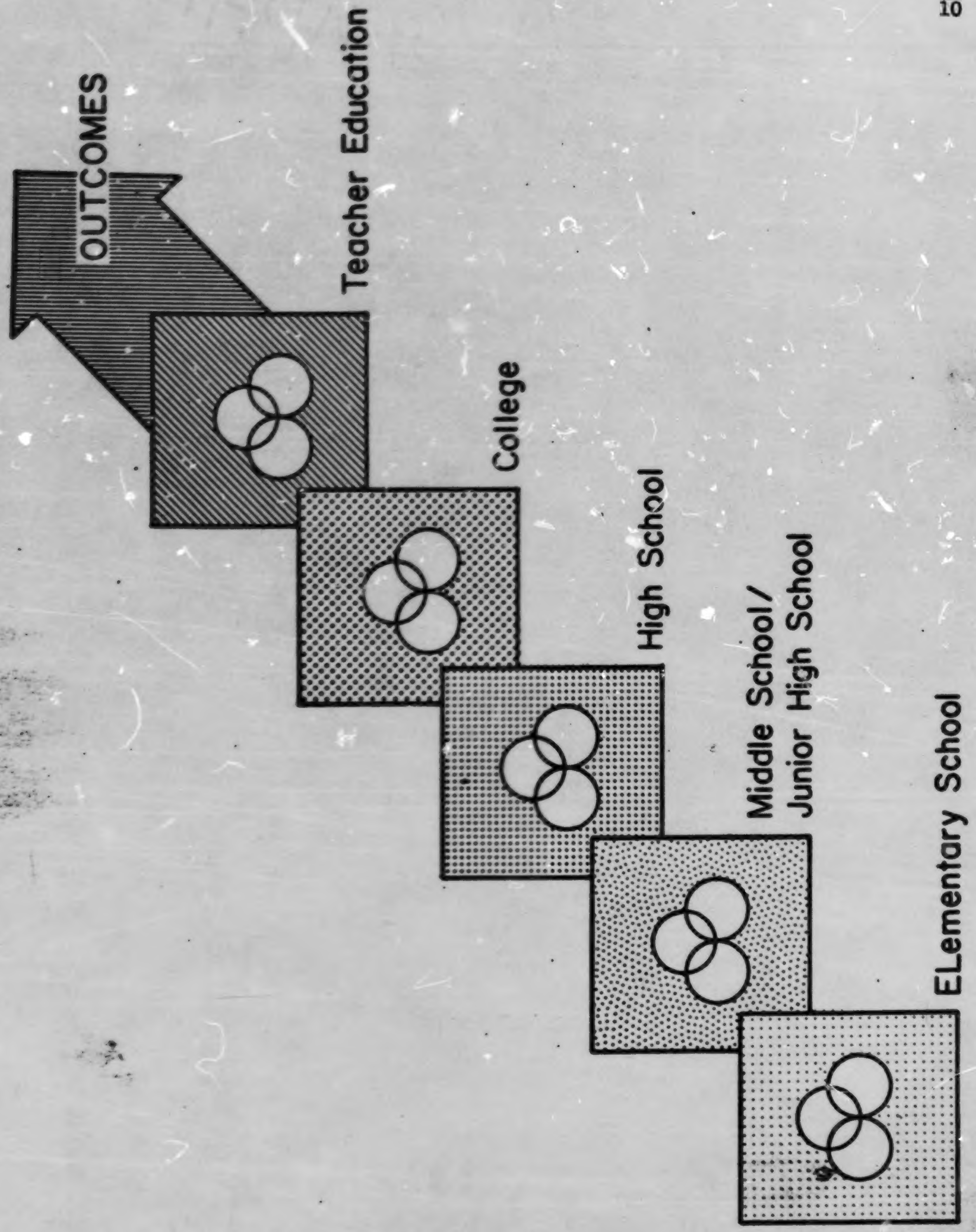

Figure 3. Articulation of science learning contexts.

We can know more about "first order" interactions of these filters

between student and teacher,
between student and instruction,
between teacher and content,
between teacher and instruction,

and how these interactions influence the science learning context and the actual outcomes.

Thus, the purpose of this review of the science education research of 1979 is to examine what we know about the "order of things" and how we can marshall these cues into a better conceptualization of the "order of ideas." From this search, we will have a basis for wiser decisions as to what we should do to further nurture the science learning context and what unknowns we need to explore. We will be letting our order of ideas indeed be a reflection of the order of things in our science classrooms.

The Research Strategies Used to Find Science Education's Order of Ideas

Research strategies may be categorized into two groups: those strategies which provide bases for describing what is--or the "describing strategies," and those that are useful for changing what is or the "improving strategies."

The Describing Strategies

In the describing group, one research strategy is historical research. This is the use of records of previous events for the purpose of arriving at generalizations by which the present may be interpreted. Recognizing the danger inherent in using one instance in history on which to base a generalization, historical or survey research is especially useful as a basis for a theory. Deductions from that theory can then be the hypotheses for further study.

A second strategy of research useful in describing "what is" is futuristic research. This can be identified as that research which attempts to predict what the future in education will be. In making these projective predictions, the assumptions about what is considered relevant in the present become explicit. For example, in his description of the future of formal education in the 21st century, Brewster (1969) clearly identifies his assumptions about what the university should be doing--namely, conveying and constructing knowledge. His university of the future reflects these assumed functions. In such futuristic projections, it is remarkable how our unstated frames of reference can become explicit and open to careful examination.

A third type is naturalistic research. In this approach, the phenomenon becomes the object of study. For example, as Atkin (1967) described this approach, the problem of generating and validating generalizations about effective teaching would be studied by a group of scholars representing different disciplines, all becoming immersed in the same classrooms at the same time. Based on their intensive study of the natural setting, descriptions of "what is" can result from imaginative and shared perceptions of scholars from quite different perceptual backgrounds. From these generalizations, new answers or solutions to science teaching can be generated.

Each of these three groups has a common denominator in that they can be used to generate more accurate information related to the precise description of what is going on in the classroom as viewed from historical, present, or future assumptions.

The Improving Strategies

A second group of strategies is directed toward improving or changing current practice in science teaching. One type is the exploratory study. In this type of study, data are collected in an attempt to ferret out relationships which the researcher intuitively believes to be present. Exploratory studies are useful to establish or demonstrate associations but do not establish cause-effect relationships. Exploratory studies do provide the opportunity to generate hypotheses about relationships which then can be pursued with empirical studies to determine their validity.

A second type is the empirical or experimental study which is usually described as the model used in the behavioral sciences. In such a strategy, a variety of research designs have been described by Campbell and Stanley (1963) as ways in which the validity of hypothesized cause-effect relationships can be established. Such a strategy is useful not as a source of ideas--but as a refining process or a search again into the cumulation of wise practice.

A third is the engineering model or strategy. In this strategy the performance objectives or expectations are delineated, and the system is designed to achieve these expectations in the most direct, and thus economically efficient, manner possible. Achievement of criterion performance is the measure of the success of the product.

The second category of research strategies is a source of specific ways to change what is known about what a teacher should do in the classroom. Through exploratory studies the potential relationships between specific teaching behaviors or patterns and students' healthy achievement can be identified. Subsequent empirical research studies can be used to demonstrate the validity of these relationships. Engineering research strategies can then be employed to develop learning conditions by which the teacher can acquire those competencies which have a demonstrated empirical validity.

In retrospect, which strategy is the most relevant? If the search is indeed one in an area of complex and multi-faceted phenomena, then a more appropriate question might be--for the task that needs to be searched anew--what is the most relevant research strategy? The logic of selecting a research strategy based on the expected outcomes of search is simple but powerful. An eclectic approach is reminiscent of Gagné's (1965) description of the search for learning theory in which he states

> Although many people including me have tried for years to account for actual instances of learning in terms of a small number of principles, I am currently convinced that it cannot be done. To the person who is interested in what principles of learning apply in education, my reply is that the question must be asked and answered with the consideration of what capability is being learned. (p. v)

In this way, researchers in science education can avoid what in other areas of research has been characterized as sterile and irrelevant research. We can omit what Wolf (1969) has described as his 5-C model which includes

> ...Cosmetic, Cardiac, Colloquial, Curricular, and Computational methods of evaluation. The Cosmetic method involves taking a cursory look at the program and deciding if it looks good, while the Cardiac method requires one to dismiss the data and believe in his heart that the new program is indeed a good one. (p. 107)

Science education researchers can function as a translator for events in the classroom setting. Based on these established relationships, and under controlled conditions, the empirical validity of these relationships between teaching style behavior and healthy student achievement can be established. This research will demonstrate what Greenwood (1945) described as the

> Natural experiment in which...(we) do not control physically what we want...(but rather) we control mentally by selecting from the environment what we need.

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SEARCHING THE SCIENCE LEARNING CONTEXT OF THE ELEMENTARY SCHOOL STUDENT

As a context in which the student learns general basic skills and specific ideas, the elementary school represents the student's first experience with formal schooling. The challenge of this context has been widely recognized in the science education literature. Beginning with research about the heart of the science learning context, the student and teacher, this section will then include descriptions of research related to the instructional context and how these are related to the outcomes of science learning in the elementary school.

The Student Filter

As seen in Table 1, 45 research studies reported results related to five elements in the complex of variables in the student filter. In most of these studies the relationship of association of a specific element to either achievement or attitudinal outcomes were investigated. In a very limited number of studies the interaction of the student variable with instructional variables was explored. These will be reported in the section on the instructional filter.

The elements of the instructional context are categories of student variables or order of ideas that emerged from a complete listing of all the student variables that were included in the 45 studies. Gender of student, the student's age or previous experience, the student's ability or aptitude, environmental variables such as socio-economic status, ethnic origin, and the student's cognitive developmental level or learning style were the five elements that seemed to encompass all the variables associated with the student filter.

In What Ways Are The Outcomes of Science Learning Different for Boys Than Girls?

In eight studies, learning outcomes were described as specific achievement knowledge or skills. In two of these studies no differences were found between the achievement of boys and girls. In a study with 59 elementary students, Smith and Litman (275) found that uninstructed girls did better than uninstructed boys on tasks requiring spatial visualization. When achievement was described as the ability to go from two-dimensional to three-dimensional conceptualization, Jones (141) found that boys did better than girls. In studying the impact of an astronomy exhibit on 138 elementary students, Sneider et al. (276) found girls achieved more knowledge and skills than did boys. However, with 140 hospitalized and well children, Denehy (71) found that boys achieved more knowledge of the body than did girls. Boys were found to achieve a greater understanding of the concept "living" than did girls in a study by Wolfinger (332).

Table 1

Research Studies Related to the Student Filter of the Elementary School Science Learning Context

		Findings					
Element	No. of Studies	Related to Achievement Outcomes			Related to Attitudinal Outcomes		
		ND	B > G	B < G	ND	B > G	B < G
Gender	11	2	4	2	1	1	1
Age/Grade Level and Previous Experiences	16	1	14	-	1	-	-
		ND	H > L	H < L	ND	H > L	H < L
Aptitude/Ability	9	3	4	-	1	1	-
Environmental Variables	4	2	2	-	-	-	-
Personalogical Variables	5	1	3	-	1	-	-
	45						

Beebe (18) found that boys tended to use more physical explanations in describing natural phenomena than did girls. Two researchers looked at differences in the cognitive development of students in the elementary school (DeLuca, 69; Mali, 193). In both studies, boys were not different in cognitive development from girls.

The attitudes of students on their preferences were outcome variables in three studies. Kishta (158) found that boys' and girls' linguistic preferences were similar. In a study with 353 sixth grade students who were in SCIS, Wareing (322) found that attitudes of boys toward science and society were substantially different from those of girls. Sneider et al (276) found several similar attitudinal differences, with girls being more positive than boys.

Does knowing student gender help a teacher understand or expect differences in science achievement in the elementary school? Based on the studies reported here, no difference was found in two instances. Boys did better than girls in four studies and girls did better than boys in two. The lack of a clear pattern supports the conclusion that the "order of things" suggests differences in achievement are probably not related to the student's gender but to other variables. A similar pattern is pictured in the three studies representing results relative to attitudinal outcomes.

At best, knowledge of a student's gender is not a useful predictor of achievement or attitudinal outcomes of science in the elementary school.

In Which Ways Are The Outcomes of Science Learning Different for Students of Different Ages, Grade Levels or Past Experiences?

The age of a child may be described in chronological terms or in terms of number of years in school. In the strictest sense, this element is one way to identify the influence of previous experience on schooling outcomes.

Of the nine studies in which age/grade level was an independent variable, eight found that older children achieved more than did younger ones. In examining the influence of an instructional strategy on unit achievement tests, Burrows and Okey (36) found that in their fourth and fifth grade sample, fifth graders consistently had higher achievement. Sneider et al. (276) found that, in her sample of 138 students, older children gained more understanding from an astronomy exhibit than did younger ones. Using six fourth- and fifth-grade classes, Werling (326) found that older children both achieved more in knowledge about their environment and in positive attitudes toward their environment than did younger students. Chavez (47) however found that in his study of two sixth-grade classes and one seventh-grade class, there seemed to be no change in attitudes toward science after they participated in an instructional program related to stereotypes of scientists. Jones (141) explored how sixth- and eighth-grade students functioned when they had to describe three-dimensional objects in terms of two-dimensional figures. With the 181 students in his study, he found that eighth graders did better than sixth graders.

Nussbaum (224) explored the concept children had of the earth with 240 fourth through eighth graders. He reported that older children consistently had more advanced concepts.

Mali (193) explored the patterns of cognitive development in Nepalese children ages 8, 10, and 12. He found that older children displayed higher development than did younger ones. Denehy (71) explored what students knew about their bodies. She found that, in her sample of 140 students, older children had a more accurate concept of both size and location of major organs of the human body. Beebe (18) explored children's explanations of natural phenomena with 96 children from grades one, three, five and seven. He found that older children tended to explain natural phenomena in physical terms, while younger children tended to use nonphysical terms.

The pattern of findings from these 9 studies suggests the strong conclusion that, when achievement is the outcome examined, older students do better in both studies where instruction is a variable and in exploratory studies. A similar pattern in attitudinal outcomes does not emerge. While attitudes do change, their changes are not consistently related to age or to grade level of students.

In seven studies found in the 1979 research reports sources, previous experiences were described in terms of out-of-school experiences (Mali, 193; Denehy, 71), in-school learning prior to the study (Doran and Ngoi, 74; Howe, 135; Thomas, 295; Werling, 326), or more specifically reading performance (Fuller et al., 100). In six of these seven studies, previous experiences were found to be important contributors to science learning outcomes. In none of those studies were attitudinal outcomes studied. Out-of-school experiences may or may not be useful predictors of achievement. With his sample of elementary Nepalese students, Mali (193) found that such experiences as places visited and games played were not correlated with measures of cognitive development. However, in her study of 140 well and hospitalized students, Denehy (71) found that the experience of hospitalization was a significant contributor to students' knowledge of the human body. With 133 third-grade students, Fuller et al. (100) found that performance on a criterion achievement measure was closely related to the student's reading level. In a study of a more general nature, Howe (135) found that sixth graders' success in SCIS was correlated with their previous SCIS experiences in earlier grades. Werling (326) found similar results with fourth and fifth graders. With 200 fifth and sixth graders, Doran and Ngoi (74) observed that previous knowledge of specific science concepts substantially aided students in understandings related to the particle nature of matter. Thomas (295), in his study with 108 fourth graders, noted that readers of a higher level did better on achievement tests that required reading comprehension.

Previous experiences of students appear to be significant factors in understanding their achievement to the extent that there is a relationship between the substances of the previous experience and the intended instructional outcomes.

In What Ways Are The Outcomes of Science Learning Different for Students of Differing Aptitude or Abilities?

Nine research studies included in their design student ability as an independent variable. In five of these studies the purpose was to explore the student's conceptual understanding as an achievement dependent variable. Nussbaum (224), in his sample of 248 fourth to eighth graders, found that students with higher IQ's had broader concepts of the earth. With 353 sixth-grade students, Wareing (322) found that students with higher IQ's had more positive attitudes toward science and scientists. In exploring the students' concept of causality, Wolfinger (332) found verbal ability was not a useful predictor of understanding in younger students (age four and a half to seven years). With 96 students in grades one, three, five, and seven, Beebe (18) also found that verbal ability seemed not to be associated with successful explanations of natural phenomena in the life sciences. With sixth-grade students, Crocker (58) found no evidence that their preférence for instructional modes was related to their aptitude.

Thus, when achievement and attitudinal outcomes of elementary students from pre-kindergarten to sixth grade are explored, measures of aptitude may or may not be useful predictors of level of achievement.

In the experimental studies in which instruction was one of the independent variables, the student's aptitude was an important factor in three of the four studies. Burrows and Okey (36) found that high mathematical aptitude was closely related to success on criterion achievement tests with fourth and fifth graders. With fourth graders, Sitkoff (273) found that underachievers could do quite well on criterion achievement tests when given instruction that matched their ability levels. In his study with 130 fifth-grade students, Kemp (149) found that scholastic ability was closely related to achievement. However, Plewes (242) explored the relationship of achievement to instructional grouping (mixed grouping or ability grouping). He found no evidence with 11 or 12 year-old students that the ability level of students was related to their achievement.

Considering both achievement and attitudinal outcomes of science instruction, student ability or aptitude appears to be a useful indicator of success. In no study did the investigator find lower ability students outperforming higher ability students.

In What Ways Are the Outcomes of Science Learning Related to the Students' Environmental Variables Such as Socio-Economic Background and Ethnic Origin?

In the 1979 research, socio-economic background and ethnic origin of elementary school students was described in four studies. In one study, Kemp (149) described it as a general indicator of home influence. With his 130 fifth graders, he found it significantly related to their achievement on a criterion achievement measure. However, in two studies (Nussbaum, 223; Mali, 193) where students' backgrounds were contrasted, no evidence was found of a relationship between socio-economic background and achievement.

One major study reported in 1979 by the National Assessment of Educational Progress (220) highlights that, at age nine, students' performance was closely related to their race with whites, Hispanics, and blacks ranked in that order. The variable of race was not found described in any other research study in 1979. Thus, a student's socio-economic background probably needs to be more adequately described in terms of the aspects of that background that are more likely expected to influence achievement.

In What Ways Are the Outcomes of Science Learning Related to the Students' Personalogical Variables?

In three studies of elementary school students, cognitive development was used as a description of Piagetian concrete or formal stages of thinking. In three studies with young children (Padilla, 233; Padilla and Smith, 234; Wolfinger, 332), the cognitive developmental levels of the students were found to be closely associated with achievement defined as understanding of an idea and ability to accurately use the idea.

However, in his study of fourth, fifth, and sixth graders, Kishta (158) did not find evidence of a relationship between level of cognitive development and achievement as measured by a standardized achievement test (Iowa Test of Basic Skills).

Learning style in the one study with elementary students was defined as the distinction between the field-independent and field-dependent student. With 253 sixth graders, Wareing (322) found no evidence that these students' attitudes toward science were influenced by their learning styles.

With too few studies of this element in the student filter on which to base a firm conclusion, it would seem that cognitive development of the student tends to be closely related to achievement outcomes that are similar to that of developmental level.

Summary

Students in the elementary school do learn science and demonstrate attitudinal outcomes related to this learning. Based on the 45 studies reported in 1979 that included an element of the student filter, it would appear that boys and girls show about the same achievement and attitudinal outcomes, older students or those with a greater past experience and those with higher ability will do better than younger, less experienced students of lower aptitude. With the exception of ethnic origin, environmental variables and cognitive developmental levels seem to not be useful predictors of student science achievement or attitudinal outcomes.

The Teacher Filter

In the teacher filter, three elements in the "order of ideas" emerge from an examination of the order of things--the research studies reported in 1979. In the science learning context, both a teacher's knowledge and pedagogical skills in planning science instruction (preactive skills) and interacting with pupils (interactive skills) are expected to be related to the quality and quantity of the outcomes. In 1979 nine research studies reported aspects of these three elements of the teacher filter.

In What Ways Are the Outcomes of Science Learning Influenced by the Science Knowledge of the Elementary Teacher?

In a survey of 489 elementary teachers in Illinois, Fitch and Fisher (95) found that teachers and administrators believed that a lack of science knowledge was the greatest obstacle to science instruction at the elementary level. Simpson (272) reported that a teacher's knowledge was directly related to pupils' desire to learn and their ability to learn. In a sample of 27 inservice teachers and their 687 pupils, Brummett (32) found that the teacher's understanding of the science content of a lesson and attitude toward that content were significantly related to pupil achievement and attitudinal outcomes. A similarly clear set of conclusions, however, was not found by Hough (133) in her study of preservice teachers' science knowledge and process skills. She found no evidence of a relationship between what preservice teachers knew and how much their pupils learned. Thoman (294) investigated the relationship between the general science knowledge of fifth-grade teachers and the achievement gains of their students. He found no evidence that a teacher's knowledge was related to pupil gains.

From a logical stance, it would seem that teachers should not be able to teach that which they do not know. From the very limited number of studies reported in 1979, the data seem to reflect evidence that says that pupils learn equally well regardless of the knowledge level of the teacher. The conflict between these two conclusions needs careful study.

In What Ways Are the Outcomes of Science Learning Influenced by the Science Teachers' Preactive and Interactive Pedagogical Skills?

In her analysis of the causes of decline in science achievement, Kahle (146) maintained that the decline is due to teachers not using the resources they have available to them. In Burke's (37) survey of the current state of science in Massachusetts what resources were available to teachers was clearly a function of size of the school system. Teachers in larger school systems had access to more inservice workshops and ideas for how to plan better instruction for their students. Olson (227) did find that teachers wanted the opportunity to decide the extent to which they were to be involved in curriculum planning and writing projects. In one research study reported in 1979, Plewes (242) found that the teacher's knowledge of, and ability to work with, individualized or mixed group instruction was significantly related to both pupil achievement and attitudinal outcomes.

While only two research studies were found in the 1979 reports in which preactive teacher skills were the independent variables, Yeany (335) reported an interesting study in which teachers described what research they would like to see given a high priority. Among their highest priorities were how teachers can influence the cognitive development of their pupils and how to plan science instruction in an interdisciplinary mode with such subjects as reading, mathematics, and social science.

In only one study was a specific interactive skill of a teacher mentioned. Simpson (272) reported a significant relationship between the teacher's expectation of pupils and the students' attitudes toward learning and ability to learn. Studies of the potential impact of teachers' interactive skills seems strangely absent in the 1979 reports of research on science in the elementary school.

Thus, at the present time, current research does not provide a basis for answering the question about how a science teacher's pedagogical skills influence achievement and attitudinal outcomes in the science learning context.

The Instruction Filter

A third area contributing to the achievement and attitudinal outcomes of students is the substance of their science learning experiences--the science instruction. In reviewing the "order of things" in the 1979 science education research reports, six categories of "order of ideas" or elements in this filter emerged. These are summarized in Table 2.

In 11 of the studies, the element can be described as content by itself, i.e., what ideas now are or should be part of the science learning context of the elementary school years. Four studies added to this question of "what ideas?" the dimension of "what ideas with what students?" One study included the topic of "what ideas with what teachers?" In nine studies, methods or instructional strategies were the variables being examined. In eight studies both the substance of the science learning content and the instructional strategy were varied. In 11 studies the complex interaction of content and method of curriculum plus selected student variables were combined to ascertain their impact on the expected achievement and attitudinal outcomes of science in the elementary school.

Table 2

Categorization of Research Studies in the Instruction Filter for Science in the Elementary School Learning Context

Element	No. of Studies
Content	
What ideas?	11
Content + Student	
What ideas with what students?	4
Content + Teacher	
What ideas with what teachers?	1
Method	
What instructional strategies?	9
Content + Method	
What curricula?	8
Content + Method + Student	
What curricula with what students?	11
	44

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Content of Instruction?

This element is primarily observed in two types of studies in the 1979 literature--surveys of what now is and descriptions of how to develop curriculum for what should be. In their survey of what now (1975-76) is happening in Illinois, Fitch and Fisher (95) found that the National Science Foundation developed curricula were reported used in 19 percent of the schools (Elementary Science Study, 8 percent; Science Curriculum Improvement Study, 7 percent; and Science--A Process Approach, 4 percent), textbooks were used in 46 percent of schools, and 35 percent reported no science instruction. Based on a sample of about 2,000 students, Treasure (305) reported that, in Alberta, third graders were weak in their knowledge of scientific methods. Votaw (316) surveyed the National Science Foundation-developed curriculum programs for their relative emphasis on environmentally-related concepts. He constructed a weighted score for Science Curriculum Improvement Study, 28; Science--A Process Approach, 25; and Elementary Science Study, 69.

Klein (159) presented a naturalistic description of science in communist East Germany as a combination of theoretical and practical experiences in industry related to the natural sciences. Science instruction begins in grade five as natural science and in grade six physics is emphasized.

The surveys seem to depict a pattern of varied opportunities to learn science in the elementary school. Shymansky and Yore (271) looked more closely at one of these opportunities--the textbook. They found that, in general, science texts show a gradual increase in reading difficulty level but that within a text, there is a very wide range of reading difficulty not well indicated by the average level reported for the texts. Chavez (47) investigated the extent to which opportunity to study explicit stereotypes of scientists through animated cartoons would influence students' attitudes and found no evidence of change.

In contrast to these studies of what-now-is, five reports described what can or should be the substance of learning opportunities for elementary school students. In these curriculum development studies, four tasks in designing and documenting a curriculum were included:

1) The establishment of goals, framework, or statement of the purpose of the curriculum--many times based on a systematic needs assessment;

2) The development of the curriculum materials which may be a selection from other sources or the writing of new materials;

3) The documentation of the impact of the curriculum which includes describing with what students and teachers and in what environment it has been found to be successful; and,

4) A description of how to implement or use the materials in new contexts--the key task of dissemination.

In Table 3 a summary is presented of the five curriculum development studies as they relate to these four outcomes. An analysis of the table indicates that a more complete documentation of both the evaluation of curriculum and the tasks to be faced in its dissemination is needed.

The extent to which specific science content of the elementary school science context is influencing student achievement and attitudinal outcomes was largely unexplored in the 1979 research. Evidence that science is, or is not, taught is presented and evidence that curriculum can be developed is available. But what is needed is knowledge about what content will influence which desired outcomes.

Table 3

Curriculum Development Studies in 1979 for Elementary School Science

		Report Decisions			
		1	2	3	4
Author	Context	Goals	Material	Evaluation	Dissemination
Butler (38)	Program for Gifted Students 3, 4, 5	x	x	x	x
Moeller (212)	School Management Curriculum Development	x	x	x	x
Lavorgna (173)	Barrier Beach Ecology Curriculum	implied	x	x	?
Akingbala (4)	Science for Grade 1 Nigeria	x	x	?	?
Kahn (152)	Science Curriculum for Pakistan	x	x	?	?

In What Ways Are the Outcomes of the Science Learning Context Influenced by an Interaction of Specific Ideas with Students of Different Characteristics?

In the absence of a base of empirical evidence that supports a relationship of specific ideas with outcomes, four studies did explore the element of what ideas with which students seem to produce the best outcomes. Nussbaum (223) studied the impact of the Science Curriculum Improvement Study's "Relativity" unit on students of differing levels of cognitive development. In his sample of 44 second and third graders he found that students who were closer to transitional stages had higher achievement. Wolfinger (332) studied four to seven year-old students and the relationship between teaching them concepts of flotation and living things and their levels of cognitive development, vocabulary development, and gender. She found that treatment group students achieved more than control group students, and that within the treatment group boys did better than girls and that concrete operational students did better than the preoperational ones. When spatial visualization was the achievement outcome, Smith and Litman (275) found that instruction helped boys but not girls.

To match the content of science to the student requires another consideration--the student's interests. Sullivan (289) reported that primary grade and intermediate grade students had a common interest in the human body but had quite different interests in such topics as living things.

The results of current research reports suggest that, while what ideas with which students might be a productive area of study, in 1979 it remained an area yet to be explored.

In What Ways Are the Outcomes of the Science Learning Context Influenced by an Interaction of Specific Ideas with Different Teachers?

Results from the studies relative to the teacher filter support the conclusion that what teachers know is directly related to their students' achievement. But in this element the focus can be more specifically on how a teacher relates to content and the impact of this relationship on the outcomes of instruction. No investigators in 1979 directly studied this interaction. Mengel (207) described aspects of curriculum development that teachers wished were included in that development. These included explicit descriptions of the teacher's expectations, the scope and sequence to show how specific instruction fits into the total picture, explicit descriptions of student outcomes, materials to match different student abilities, suggestions for management of learning, and teacher inservice materials.

Informal experience suggests that given the same content, outcomes may vary widely among teachers. Research is needed in this area to better understand possible causes.

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Instructional Strategies or Methods Used?

If there is a useful distinction between strategy as a global phenomenon and tactic as a specific event then, in the 1979 research reports that deal with instructional methodology, the range is present. Examining the strategy of using field experiences or not using them, Gross and Pizzini (110) found that those students who had field trips also showed greater achievement and positive attitudes toward the environment than did those who had only in-class instruction. Pines (240) found that instruction that was organized in an inductive or a deductive mode seemed to be helpful, depending on the concepts to be learned. In studying second graders, Kruse (164) hypothesized that formal instruction on reading in the content areas would result in different reading comprehension than would an informal emphasis. No evidence was found to support this hypothesis. Trainor (303) used 75 students to find that investigation followed by a directed discussion resulted in higher achievement than did investigation followed by nondirected discussion. Davis (66) also found that a guided discussion was more effective in influencing student achievement than was an expository textbook.

In these studies, the unmentioned variable that may well be accounting for much of the impact is the teacher. This is also seen in several studies in which specific tactics are the independent variables. Holliday and Partridge (128) presented evidence that using pictures to help students visualize correct examples influenced their achievement. In a sample of 31 second-grade classes, Billings (19) found that students having only concrete experiences achieved significantly more than did students having both concrete experiences and verbal labels for two concepts (interaction, evidence of interaction). Tobin (298) found that the teacher tactic of wait-time was significantly correlated with achievement. Students in the longer wait-time groups achieved more. In a less specific tactic, Crocker (58) did not find evidence that high or low teacher control was related to achievement.

Some evidence suggests that global strategies may be associated with increased achievement. Much clearer evidence exists in a relationship between specific tactics and achievement and attitudinal outcomes.

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Interaction of Specific Ideas and Instructional Strategies?

The combination of the content and method of instruction is one operational definition of a curriculum. In the eight studies that reflect this element, three described the impact of a curriculum program on student achievement and attitudinal outcomes. In four studies, hands-on instructional approach, and in one study a survey of biology concepts plus method of instruction was made. In this study, Lucas

(186) found that, at the elementary level, there were no common patterns of biology concepts in six programs surveyed. She did find, however, that there was a common pattern in the presentation of the concepts, with sentence influence being the most common; graphic illustrations, second; environmental examples, third; demonstrations, fourth; and simple statements least frequently used.

When curriculum programs were contrasted, Esler (92) found, in his study of 120 third and fifth graders, Science--A Process Approach did not seem to help students remedy a communication skills deficiency. Hofman (124) studied the impact of Science Curriculum Improvement Study on eight year-olds and found no evidence that instruction with Science Curriculum Improvement Study was related to their attitude toward science. In contrast, Haan (112) found that a student's attitude toward science was related to Science Curriculum Improvement Study instruction.

A possible reason for the inconsistent results may be the global or general nature of the independent variable in these studies. It may be that studies of a specific aspect of a program (rather than the total program) would result in evidence of relationships between the curriculum and the outcomes.

Hands-on instruction and textbook instruction both outside and within the classroom have been contrasted with a number of alternatives. In a study with 284 fourth, fifth, and sixth graders, Story and Brown (285) found a significant change in student attitude toward science when hands-on instruction was compared with textbook instruction. In the absence of a specific description of the topic and substance of these treatments, it is assumed that both content and methodology were different. Cohen (50) hypothesized that hands-on instruction would result in modification of students' cognitive development. With his sample of 36 first, third, and fifth graders, however, he found no evidence to support this hypothesis.

Case (43) looked at the effects of an eight-week unit on environmental education on environmental knowledge and attitudes of sixth-grade students. Treatment group A received a one-week field experience as a part of the unit. Treatment group B studied the eight-week unit in the classroom. Control group C had no environmental curriculum activities. When knowledge outcomes were measured, results favored group B. When attitudinal changes were studied, control group C had significantly higher scores than did group A. There was no significant difference between groups B and C on the environmental attitude inventory.

Werling (326) used a sample of 120 fourth and fifth graders to evaluate the contrasting achievement and attitudinal outcomes of three curricula: a modified hands-on outdoor unit from Outdoor Biology Investigations in Science, a hands-on classroom unit from Science Curriculum Improvement Study, and an in-class lecture. He found that all three groups showed similar achievement but that the outdoor group showed the greatest change in attitudes toward the environment.

The mixed nature of the results of these studies in the element of content/methodology may be a function of using a global independent variable that itself may well be a complex combination of many separate elements. At the elementary level, even within such a complexity of interactions, it would appear that curricular experiences that permit greater personal involvement of the student are likely to result in increased achievement and positive attitudinal outcomes.

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Interaction of Specific Content, Instructional Strategies and Students of Differing Characteristics?

In two studies science learning outcomes were compared for a specific curriculum (Science Curriculum Improvement Study) with student characteristics used as blocking variables. To answer the question: with what students is Science Curriculum Improvement Study more successful in influencing attitudes toward science?, Wareing (322) compared Science Curriculum Improvement Study classes with non-Science Curriculum Improvement Study classes. She found that the most significant factors that influenced attitudinal change were the student's IQ and gender and not cognitive style nor instruction in Science Curriculum Improvement Study. In contrast, Howe (135) studied the relationship between Science Curriculum Improvement Study (SCIS) achievement and the following of the SCIS sequence, the past success of students in SCIS, and student participation in small groups. She found no evidence that the students' experience in small group participation or in having participated in SCIS in previous years was related to a criterion SCIS achievement test. She did find that the students' previous success in SCIS was significantly related to their achievement.

With younger students (120 first graders) Padilla and Smith (234) studied the relative impact of two strategies for serial ordering with students of differing cognitive development. They found that there was a strategy-developmental interaction. Linn (180) studied contrasting settings for deaf students and found that there was no evidence that deaf students in a resource setting had achievement differences from those in mainstreamed setting. She did find, however, that those in the resource setting participated in more student activity. Plewes (242) also looked at the contrast between students in a mixed ability individualized setting or in a single ability group instructional setting. He found that lower ability students did better in the mixed individualized instructional setting.

Sneider et al. (276) found that older girls gained more in achievement and attitudinal outcomes when they participated in an astronomy exhibit. Kemp (149) hypothesized that hemisphere-oriented instruction would have a different impact depending on the background of the student. In contrasting instruction of verbal-nonactivity oriented (left hemisphere) or holistic activity-oriented (right hemisphere), he found no evidence of a relationship of instruction, student variables, and achievement. Fuller et al. (100) compared the difference in achievement for third-grade students whose source of information was a book or puzzles. They found no evidence of a treatment-related difference but found that high ability students consistently showed greater achievement. A similar finding by Thomas (295) was that high achievement students performed better regardless of the treatment. With 84 fourth and fifth graders, Burrows and Okey (36) found that a full mastery learning instructional strategy resulted in greater achievement. As they predicted, the full mastery model group also showed a significant reduction in variance on achievement. Such a strategy may provide a key for helping solve remediation problems. Sitkoff (273) also found that, when instruction was designed for the slower or remediation students, they could learn.

To answer the question of what ideas taught in what way with what kinds of students will provide the best achievement and attitudinal outcomes seems rather simple and easy. Finding an answer to this question is still a challenge. Do we need to think more carefully about what ideas with what methods and with what students will influence what the students do while in the instructional context? It may be that the key is not a relationship between the instructional filter and achievement and attitudinal outcomes, but in areas unreported in 1979 research: relationships between the instructional filter and student behavior in the learning context.

Summary

In the 100 studies in which the science learning outcomes of elementary school students were studied, variations in these outcomes were found to be described in terms of the elements of these filters.

The Student Filter (n = 45 studies)

A. Gender - no consistent differences found

B. Ability/Aptitude - higher ability students do better than do lower ability students

C. Previous Experience - older students do better than do younger students

D. Environmental Variables - ethnic origin is a significant contributor to academic achievement

E. Personalogical Variables - too few studies to establish a pattern of results

The Teacher Filter (n = 11 studies)

A. Teacher Knowledge - no findings to indicate teachers' knowledge makes a difference on achievement

B. Teacher Pedagogical Skills - too few studies to establish a pattern of results

The Instruction Filter (n = 44 studies)

A. Content - an unexplored area

B. Method - global methods or treatments are correlated with achievement--especially if they enhance higher personal involvement of students

SEARCHING THE SCIENCE LEARNING CONTEXT OF THE EMERGING ADOLESCENT

The emerging adolescent is a complex matrix of dynamic physical and mental changes. The uneven spurt-like quality of these changes can be confusing to the student and to the teacher. It is within this context of a personal need to be acclimated to a new self that the student meets with systematic science instruction. For many this is their first formal science classroom experience. In this section the research studies in science education related to this perplexing and challenging learning context are described in terms of how the student filter, the teaching filter, and the instructional filter influence science learning outcomes.

The Student Filter

In 1979, 64 research studies reported elements of the student filter in their design. The elements related to students were grouped in five categories: gender, ability/aptitude, age/previous experience, environmental, and personalogical. In Table 4 a survey of the findings related to the student filter is given. Clearly a high concern of knowing more about students in the middle/junior high school science learning context is reflected in the 1979 studies.

In What Way Are the Outcomes in Science Learning Different for Boys Than for Girls?

The extent to which boys' and girls' attitudinal outcomes are similar for seventh, eighth, and ninth graders was examined in four studies. With a sample of 991 junior high school students in Israel, Lazarowitz and Lazarowitz (176) found significant differences between boys and girls on topics of interest. Experience also confirms that all students do not welcome new science topics with equal enthusiasm. D'Annucci (63) also reported, with a sample of 505 grade 7-12 students, significant differences between boys' and girls' attitudes toward science and science teachers as measured by a semantic differential instrument. In his study involving 149 seventh, eighth, and ninth graders, Vinelli et al. (315) found girls tended to be much more dependent on teachers than did boys. However, Alaimo (5) did not find a gender-related difference in the value preferences of environmental problems. Based on this group of four reported studies, science teachers can expect attitudinal outcomes for boys to differ from those for girls.

Achievement-related outcomes were examined in nine studies. In three of these studies the achievement outcomes were measured by a criterion achievement test based on the Intermediate Science Curriculum Study program. McDuffie (201) studied 769 ninth graders and Stolper (284) studied 129 ninth graders. Both found no gender-related differences. However, Young (339), in her sample of 300 ninth graders, found girls had higher achievement than boys in ISCS.

Table 4

Research Studies Related to the Student Filter in the Middle/Junior High School Science Learning Context

Element	No. of Studies	Findings					
		Related to Achievement Outcomes			Related to Attitudinal Outcomes		
		ND	H > L	H < L	ND	H > L	H < L
Gender	16	7	4	1	1	2	1
Ability/Aptitude	12	4	7	-	-	1	-
Age/Previous Experience	13	3	7	-	1	2	1
Environmental Variables	6	1	5	-	-	-	-
Personalogical	17	2	11	-	1	3	-
	64						

Another measure of achievement was standardized tests. In a study of seventh, eighth, and ninth graders, Hayes (120) found no achievement difference between boys and girls. Davies and Fowler (65) also found no differences, as was also true in a study of 113 eighth graders by Evans (93). Using locally developed measures, LaHart (169) studied the knowledge of the environment of 1,300 eighth graders. He found boys scored significantly higher than girls. Using 1,635 Tasmanian junior high school students, Lynch et al. (189) also found that boys performed better than girls on a test of definitions of science terms. But in contrast, Egolf (88) used 525 seventh and eighth graders to determine that there was no evidence of a gender-related difference in solving word problems in science. The National Assessment project (220) reported that age 13 boys outperformed girls on all items and categories except on those questions that dealt with scientific decision making. Girls did significantly better than boys on those questions.

Thus, in terms of achievement outcomes from science learning, the results present a very mixed picture. Natural Assessment data would seem to indicate that in most any science learning context, one should expect to find boys outperforming girls. In the 1979 reports this achievement pattern just does not occur. The reason for this apparent contradiction is unclear.

An additional aspect of outcomes of schooling is the hypothesis that instruction does indeed influence student cognitive development--and that this influence may not be exactly similar in both boys and girls. In a study of six intact classes of ninth graders, Brown (29) found boys did better than girls in the ability to use proportionality concepts. But, in his study with 300 seventh, eighth, and ninth graders, Hayes (120) found no difference in propositional reasoning between boys and girls.

Knowing a student's gender does not seem to serve as an unfailing predictor of success in the middle/junior high school science learning context.

In What Ways Are the Outcomes of Science Learning Different for Students of Different Aptitudes or Ability?

At the outset of a school year, most teachers would expect the science achievement of high ability students to be better than that of lower ability students. Out of the 13 studies in which an ability/aptitude level was examined, this expectation was confirmed in nine studies. In one of these studies, Griffin (109) found that higher ability students had much more positive attitudes toward science than did middle or lower aptitude students.

In ten studies achievement was measured by a criterion achievement test. In six of these studies, the test was designed to measure the outcomes of Intermediate Science Curriculum Study. In a study of 769 ninth graders, McDuffie (201) found that high verbal and quantitative SCAT performers did significantly better in Intermediate Science Curriculum Study. Similar results were also reported in another study by McDuffie (202) with a sample of seventh, eighth, and ninth graders.

When aptitudes were defined as reading performance, Greene and Szabo (108) found that, in 114 ninth graders, high aptitude was related to high achievement. A similar finding by Howe and Early (134) supports an important relationship between reading ability and success in Intermediate Science Curriculum Study. A third study which confirms this conclusion, involved 129 ninth graders. Stolper (284) found a high correlation between reading ability and scholastic ability (as indicated by DAT) to success in Intermediate Science Curriculum Study. However, Hagenbuch (113) did not find this relationship between IQ as an aptitude indicator and Intermediate Science Curriculum Study achievement.

This set of studies would strongly suggest that aptitude is a strong predictor of success in the Intermediate Science Curriculum Study program.

In four other studies, criterion achievement tests were used. With IQ as the indicator of aptitude, Evans (93) found no evidence of a relationship between aptitude and achievement with 113 eighth graders. Young (339) also used IQ and critical thinking as indicators of ability and found a significant correlation between them and achievement. In his study of 1,635 junior/senior high school students, Lynch et al. (189) found IQ to be the strongest predictor of success in recognizing definitions of science terms. However, Bowyer (27) used SRA scores as measures of ability with 193 seventh graders and found no evidence of an ability-achievement relationship. When Amien (7) used over- and under-achievers as an independent variable, he also found no relationship between this as an indicator of ability and student achievement.

In general, the 13 studies would suggest that students of higher ability or aptitude tend to do significantly better on measures of science achievement than do students of lower ability or aptitude.

In What Ways Are the Outcomes of Science Learning Different for Students of Contrasting Ages or Previous Experiences?

Studies in this group tended to contrast students' grade level as an indicator of their age or related previous experience. In three studies, no evidence was found to support a relationship between a student's grade level (seventh, eighth, and ninth) and an achievement measure such as a test of science knowledge (Davies and Fowler, 65) or a criterion achievement measure (Stolper, 284; LaHart, 169). However, in eight studies, older students were found to do better on a variety of achievement measures. In a sample of 1,635 seventh to twelfth graders, Lynch et al. (189) found that older students did better in their recognition of definitions of science. McDuffie (201) found eighth graders did better than seventh graders on a criterion achievement measure in the Intermediate Science Curriculum Study material. Egolf (88) observed that eighth graders did better than seventh graders in solving word problems in science. In a study of seventh, eighth, and ninth graders, Hayes (120) found ninth graders did better on the

STEP test. Based on his sample of 108 eighth, tenth, and twelfth graders, Treagust (304) concluded that older students did better in spatial visualization tasks than did younger ones. King (154) also found that ninth graders did better than eighth graders on a criterion achievement test on knowledge of the environment. The NAEP study (220) also found significant differences between seventh and eighth graders (13 year-old students).

The pattern of results observed in these studies suggests that the longer students are in school, the better they may be expected to do on achievement measures.

Attitudinal outcomes have been examined in four studies as they relate to middle/junior high students. While Davies and Fowler (65) did not find students in grades seven, eight, and nine showing differences in attitudes toward science, Lazarowitz and Lazarowitz (176) did find that students of these grade levels had pronounced differences in preferences for science topics. In his sample of 1,300 students from urban and rural backgrounds, LaHart (169) found an attitudinal pattern that closely paralleled the previous home experiences of the student. In his study of 615 students in grades seven to twelve, Alaimo (5) found that younger students had more positive value preferences than had older students.

While grade level as an indicator of previous experience is a useful predictor of achievement, it does not appear to be a useful indicator of student attitudinal outcomes.

In What Ways Are the Outcomes of Science Learning Related to the Students' Environment Variables Such as Socio-Economic and Ethnic Origin?

Parent background, urban/rural home location, social mobility, and race are examples of indicators of this element of socio-economic environmental variables that could be expected to influence student achievement. In the six studies which included this variable, race was the specific indicator in five studies--and in four of the five studies, it was found to be significantly related to achievement. LaHart (169) studied 1,300 eighth graders and found that race, parent background and urban/rural home location were significant predictors of success on a criterion achievement test on ecological knowledge. Saunders and Yeany (260) in their study of three seventh-grade classes found white students did significantly better than blacks on a criterion achievement test. However, Stolper (284) did not find this true in his study of 129 ninth graders given a criterion achievement measure in ISCS. Ashrafi (9) studied 137 junior high school Persian and American students and found a significant difference in information recall. In the National Assessment (220) results with 13 year-olds, whites did significantly better than Hispanics who in turn did better than blacks. In one study, social mobility was used as the indicator of this element. Lynch et al. (189) found that in a sample of more than 1,500 Tasmanians social mobility was closely related to success in recognizing science concept definitions.

In the limited number of studies which included aspects of the environmental element as independent variables, the outcomes clearly suggest that this element should receive very high consideration. The extent to which these results are descriptors of what now is or are descriptors of limits of what can be represents an urgent, and to a large extent unresearched, question.

In What Ways Are the Outcomes of Science Learning Related to Personalogical Variables?

In the studies of middle/junior high school students, six described the stages of student cognitive development as a variable thought to influence achievement. In five of the six studies, evidence was found to support this assumption. In a study of 112 junior/senior high school students, Lowell (183) found that formal thinkers did better than concrete thinkers on a test on classification. Howe and Early (134) found similar results when they used a criterion achievement test in Intermediate Science Curriculum Study classes. Using the STEP test as the achievement indicator, Hayes (120) also found formal thinkers did better than concrete thinkers. In contrast, however, Stolper (284) did not find evidence to support a relationship between level of cognitive development and achievement in Intermediate Science Curriculum Study. When cognitive development was described as ability to do propositional thinking, McBride and Chiappetta (200) found significant correlations between it and a criterion achievement test on simple machines and structure of matter. With a sample of six intact classes, Brown (29) found a relationship between conservers and nonconservers and their ability to reason proportionally.

Based on these six studies, a trend emerges that suggests that knowing a student's present level of cognitive development is helpful in predicting success in the science learning context.

In two studies in which aspects of the student's learning style were described, Saunders and Yeany (260), with three seventh-grade classes, found that "internal" students did better on a criterion achievement test than did "external" students. With his sample of 71 students, Hagenbuch (113) found that the part/whole dimension learning style was associated with success on an achievement test of science process skills.

The two studies are interesting but provide a rather limited basis in a search for a relationship between learning styles of students and their achievement.

Other personalogical variables such as motivation, flexibility, work style, attitude, self-esteem, or self-perception have been examined in six studies of middle/junior high school students. In the three studies in which student attitude was used as a predictor of achievement, a significant relationship was found. Students with positive attitudes do better (McDuffie, 201, 202; Hagenbuch, 113).

A similar pattern for other personalogical variables did not appear. Young (339) found that neither student self-esteem nor preference for instructional method was related to achievement in Intermediate Science Curriculum Study. However, in two studies McDuffie (201, 202) found that student work style was significantly related to achievement in Intermediate Science Curriculum Study. Alaimo (5) studied 615 seventh to twelfth graders and found that their self perceptions were related to their preferences in solving environmental problems. But, in his study of three seventh-grade classes, Amien (7) found no evidence of a relationship between personality measures and achievement in geology.

It may be that the impact of variables in this element of the student filter are better observed in the instructional context rather than in the outcomes of instruction. Since the results do not support a strong relationship between personality characteristics and achievement, it may be that looking for relationships between the students' personalogical variables and their behavior in the instructional context is a more useful area of research.

Summary

Emerging adolescents learn science and demonstrate positive attitudes toward their learning. Based on the 64 1979 research studies that included an element of the student filter, it would appear boys and girls do not consistently show differences in their achievement; students with higher aptitude do better than those with lower aptitude; the longer students have been in school, the better they will do in achievement outcomes although a similar pattern for attitudinal outcomes was not found; environmental variables such as home background and ethnic origin appear to be significant contributors to outcomes of the science learning context; variations in personalogical variables such as cognitive development level, learning style, motivation, and attitudes show significant correlations with achievement and attitudinal outcomes. The extent to which some of the elements of the student filter are limiting factors on science learning or are factors that themselves can be changed is a challenge that must be marked for continued study.

The Teacher Filter

In the three research studies reported in 1979 that included elements of the teacher filter, each one reported significant differences between the teacher element and student achievement. With 172 pupils, Horton (132) found that teacher knowledge was directly related to how much the students learned in Intermediate Science Curriculum Study. He also found that the degree of commitment a teacher had to the philosophical orientation of Intermediate Science Curriculum Study was significantly correlated to pupil achievement. McDuffie (201), in his study of 769 seventh and eighth graders, found a significant correlation between what teachers expected students to achieve and student performance on a criterion achievement test. The inference can be drawn that if a teacher believes a student can be successful--the student usually will be. Speece (277) reported on factors that students said influenced them to participate in science fairs. A significant factor was their belief that the teachers thought it was a desirable thing to do.

That teachers influence their pupils is a widely accepted truism. How specific elements of the teacher filter facilitate this influence is an unexplored area of research in the 1979 studies.

The Instruction Filter

In this third filter, there are two elements that are identifiable as sources of variation in student achievement or attitudinal outcomes in the science learning context. These elements are the content of instruction and the strategies or methods of instruction plus the interactions between these elements and elements of the student and teacher filters. A summary of the 22 studies for these elements and their interactions is presented in Table 5.

Table 5

Categorization of Studies in the Instruction Filter

Elements	No. of Studies
Content	
What ideas?	6
Content + Student	
What ideas with what students?	1
Content + Teacher	
What ideas with what teachers?	-
Methods	
What instructional strategies?	4
Content + Method	
What curricula?	2
Content + Method + Student	
What curricula with what students?	9
	22

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Content of Instruction?

In three of the studies reported in 1979, surveys of specific science concepts describe what students need to know. Treasure (305) reported that eighth graders in Alberta were weak in earth science. Jorgensen's (144) study described what concepts in outdoor education should be included in the junior high school. Schlenker and Cronwell (263) describe what concepts in marine education should be taught. These studies were attempts to ascertain which ideas should be included in science instruction based on surveys and opinion consensus.

A second approach to deciding the content of instruction is to secure empirical evidence that the content makes a difference in student achievement. Russell (256) studied the impact of specific instruction with a problem solving model on the problem solving behavior and critical thinking of 287 eighth graders. He found that instruction produced significantly better achievement than the use of a conventional textbook in comparison classes. Egolf (88) also found that treatment and control groups were significantly different in their problem solving behavior when given specific instructions in solving word problems. In her study with six classes of ninth graders, Brown (29) found that teaching students proportional reasoning resulted in differences in achievement.

Clearly, the evidence suggests that instruction in specific content may be expected to result in increased criterion achievement performance.

In What Ways Are the Outcomes of Science Learning Influenced by Interactions of Specific Content and Students in the Instructional Context

McMillan and May (206) reported the only study of this element. They interviewed 53 seventh, eighth, and ninth graders to find out what factors the students thought influenced their attitudes toward science. In general, boys said they liked science more if the content was useful. Girls seemed to say they would like science anyway.

Student interest in the content seems to be an important area for research study--but the reports of 1979 suggest that during that year it was largely unexplored.

In What Ways Are the Outcomes of Science Learning Influenced by an Interaction of Specific Content and Different Teachers?

No studies were found in the 1979 research reports in which the researcher explored how teachers may be interacting with science content or curricula. Informal experience would suggest that this interaction has the potential of explaining a large amount of variance in student outcomes. Empirical evidence is needed to help understand what elements of the teacher filter may be interacting with the instruction filter to produce differences in student behavior and outcomes.

In What Ways Are the Outcomes of Science Learning Influenced by the Instructional Strategies or Methods Used?

Instructional strategies described in the four studies of this element were the use of advance organizers, graphs, and simulations. Sherbo (267) compared the use of advance organizers with not using them and found no evidence that their use was related to student achievement. Batty (15) did a similar study with 95 eighth graders with similar results on a criterion achievement test on oceanography. Dunlop (81) compared the use of an energy simulator with conventional instruction. He found that students in the treatment group and their teachers had significantly more positive attitudes toward energy than had the comparison groups. With a sample of 265 seventh graders, Roller (252) contrasted the instructional strategy of integrating graphs in the text with having them isolated from the text. She found that students who had the isolated graphs did significantly better in reading and interpreting graphs.

The four studies related to aspects of this element are encouraging. They provide explicit empirical evidence as to the usefulness of specific instructional strategies. This is in contrast to many "Method A" versus "Method B" studies in which the method itself is so global that it is nearly impossible to describe definite patterns in student outcomes.

In What Ways Are the Outcomes of Science Learning Influenced by the Interactions of Specific Content and Instructional Strategies?

In a more general sense, the content and strategies of instruction can be defined as the science curriculum. Two studies reported looking at aspects of this element. Davies and Fowler (65) compared student achievement and attitudinal outcomes where students had the option of a set of elective minor courses or the textbook. They found no differences in either achievement or attitude. King (154), however, compared the influence of both the content and strategy of using field experiences. In one treatment group they had field trips before class instruction. A second treatment group had class instruction before the field trip. A third group had the class instruction only and the fourth group of the 618 eighth graders had the field trip. King found that students who had the field trip then class instruction achieved the most, followed by students who had class instruction and then the field trip, and last, students who had the field trip only. These three groups all did significantly better on the criterion achievement test of environmental knowledge than did the in-class instruction only group.

When the total curriculum is the independent variable, it is possible to find significant differences in the outcome measures.

The power of the treatment must be tremendous for it to surface through all the other variables that may be mixing below the observation level of the researchers.

In What Ways Are the Outcomes of Science Learning Influenced by the Interaction of Specific Content, Instructional Strategies and Students of Differing Characteristics?

In the nine studies that provide data for this element, there is a range of magnitude in the independent variables thought to influence instructional outcomes from a contrast of a total curriculum package to contrasts in teaching style to contrasts in specific order of instruction in a lesson.

Using a larger time format, Milson (210) studied the impact of a hands-on curriculum as compared with "read-about" science instruction with six classes of below-level reading students. He found that the hands-on approach resulted in significantly better attitudes toward science. Hagenbuch (113) contrasted the student outcomes of science process skills and attitudes of 71 students in classes of Introductory Physical Science and Intermediate Science Curriculum Study. He found significant differences between the classes to be related to student aptitude and cognitive style. When Greene and Szabo (108) developed a modified reading level of Intermediate Science Curriculum Study, they found that students of different abilities in the treatment group did not seem to benefit from the modified reading materials based on a criterion achievement test in Intermediate Science Curriculum Study.

Amien (7) contrasted the impact of a modular student-centered curriculum with a conventional teacher-centered curriculum. When the results of the achievement and attitudes of the students were analyzed, no evidence was found that student aptitude and personality variables or instructional treatments were associated with the outcomes. Griffin (109) studied the order of instruction: using a visit to a planetarium before class instruction or using it as a review after class instruction. He found that high achieving students' attitudinal outcomes tended to decline after planetarium visits. With a sample of 113, Evans (93) contrasted both the order of science presentations (demonstration then theory or theory then demonstration) and the degree of unexpectedness in the event (expected or surprising) with students of varying IQ, science achievement and gender. He found no evidence to support that either order or degree of unexpectedness and student characteristics influenced achievement. Bowyer (27) hypothesized that the type of advance organizer (verbal or visual) would interact in different ways with students of contrasting ability. No difference in a criterion achievement test were found. Saunders and Yeany (260) used three classes of junior high school students to study the impact of instruction in which one group received diagnostic tests and remediation, a second group reviewed the diagnostic test only and the third comparison group had the instructional objects. They found that the diagnostic test and remediation group had significantly greater achievement on a criterion test. They also found that the learning style of students and ethnic origin were significantly related to the outcomes.

"Internal" white students did better in this instructional mode than did blacks or those with an "external" learning style. Vinelli (315) also found that the mode of instruction (teacher control or student control) was related to a dependent variable--the degree of dependency on the teacher that students exhibited.

Reflecting on these studies, the evidence is weak at best that content and instructional strategies have different influences on students of different characteristics. Two factors may be confusing the research. First, the independent variables may be too global or too unspecific for us to precisely identify what treatment and effect may be expected. Second, it may be that the direct observation of impact is more productively made of what students do in the classroom rather than of terminal outcomes. If what students do while learning is linked to what is learned (an unexplored area in the 1979 reports of science education research), then studies on how to use the science curriculum to modify what students do are essential.

Summary

In the 89 studies in which the science learning outcomes of the emerging adolescent were studied, variations in these outcomes were found to be described in terms of the elements of these filters.

The Student Filter (n = 64 studies)

A. Gender - no consistent differences found

B. Ability/Aptitude - higher ability students do better than lower ability students

C. Previous Experience - the longer students are in school, the higher their achievement

D. Environmental Variables - ethnic origin and home background are clearly associated with achievement outcomes

E. Personalogical Variables - formal thinking students do better than concrete level students; too few studies involving learning style and motivation were reported to ascertain a trend

The Teacher Filter (n = 3 studies)

A. Teacher Knowledge - too few studies to establish a pattern

B. Teacher Pedagogical Skills - too few studies to establish a pattern

The Instructor Filter (n = 22 studies)

A. Content - instruction in specific content increases achievement

B. Method - some instructional tactics are related to achievement and attitudinal outcomes

SEARCHING THE SCIENCE LEARNING CONTEXT OF THE ADOLESCENT

High school--the place for serious preparation for college days or the terminal schooling for the student--illustrates an immense challenge. Should the context be directed toward providing an academic foundation for college students or a vocational emphasis for students who view high school graduation as completion of schooling?

In this section, the research studies will show new evidence that the final word is yet to be pronounced as to what can or should be the outcomes and most useful interactions in this context.

The Student Filter

In the science education research reported in 1979, there were 75 studies that included elements of the student filter. These elements have been grouped into five categories--gender, ability/aptitude, age/previous experience, environmental, and personalogical. In Table 6 a survey of the findings is given.

In What Ways Are the Outcomes in Science Learning Different For Boys Than For Girls?

The difference between girls' and boys' achievement in science was examined in ten studies reported in 1979. In seven of these studies no differences were found. With the 25 students in his sample, Stitt (283) found no evidence of a gender-related difference on a criterion achievement test. Stephenson (282) studied 86 high school chemistry students and found boys did as well as girls on a criterion achievement test. McGahan's (203) results with 102 chemistry students were similar. Cohen (51) looked at the problem solving of 223 high school students and found no gender differences in their performance. With a sample of 60 twelfth graders, Brown and Butts (30) found that boys did as well as girls on a criterion achievement test in human physiology. In his sample of 36 secondary students, Wormack (333) found boys' and girls' performance similar on the STEP test. With 129 tenth graders in Jordan, Kishta (158) found that the cognitive development of boys was similar to that of girls in his study.

In contrast to this trend of no gender-related differences, however, Jimenez and Rosendo (140) found that boys did better than girls on a criterion achievement test in physics and on the Wisconsin Inventory of Science Process. The National Assessment (220) results for 17 year-olds clearly showed boys doing better than girls in every area except decision making--an area of excellence for the girls. Thompson's (296) results show that British girls differed from boys on their physics examination performance.

Table 6

Research Studies Related to the Student Filter on the High School Science Learning Context

Element	No. of Studies	Findings					
		Related to Achievement Outcomes			Related to Attitudinal Outcomes		
		ND	H > L	H < L	ND	H > L	H < L
Gender	17	7	2	1	6	1	-
Ability/Aptitude	10	1	5	-	3	1	-
Age/Previous Experience	16	7	6	-	3	-	-
Environmental	11	2	2	-	3	4	-
Personalogical	21	3	14	-	1	3	-
	75						

Attitudinal outcomes that have been studied include students' attitudes toward science, curiosity interests, and interest as expressed in their selecting additional science courses. With a sample of 413 tenth, eleventh, and twelfth graders, Kuhn (167) found boys to have a more positive attitude toward science than had girls. In his study with 276 Israeli high school students, Tamir (291) found no differences in the scientific curiosity of boys and girls. Gay (103) found no gender-related factors in course enrollment but Omerod et al. (228) found that boys tended to select physics especially if classes were coeducational. In contrast, girls tended to request physics if the classes were limited to girls only. In four other studies, no evidence for a gender-based difference was found in students' attitude (McGahan, 203), attitude toward the environment (Kudlas, 166), interest in science (Stitt, 283). In a study of 86 students, Quint (246) found that attitude changes in parents as a result of their children's science experiences was similar regardless of the gender of the student.

While the results of four studies do not explicitly fit this conclusion, most of the studies (n = 13) reporting gender as a variable show evidence that at the high school level, boys and girls can be expected to have similar achievement and attitudinal outcomes.

In What Ways Are the Outcomes of Science Learning Different For Students of Different Aptitude or Ability?

Teachers usually expect students with known high aptitudes or abilities to do better in science than students with less ability. In the ten studies in which this element has been included, this seems to be true for achievement but not for attitudinal outcomes. Brown and Butts (30) found that twelfth graders with higher IQ's did better on their criterion achievement test in physiology. Zvi et al. (340) examined the performance of 440 tenth and eleventh grade Israeli students in chemistry and found it closely correlated with IQ. In Jones' (142) study, a similar conclusion was found. Lueckemeyer (184) used the DAT as a measure of aptitude and found it significantly related to a criterion achievement test. In his study with 93 high school biology students, Long (181) found a strong relationship between attitude and achievement in biology. In one contrasting study, however, Grant (107) found no aptitude-related differences in the written problem solutions of tenth, eleventh, and twelfth graders.

When attitudinal outcomes of science learning are considered, an opposite trend is observed. No aptitude differences in students' attitudes were found by Brown and Butts (30), Long (181), and Kudlas (166). In his sample of 75, Quint (246) did find that parents of high ability students showed greater changes in their attitudes toward the environment than did the others in the sample.

As would be expected, the results of these studies support the conclusion that brighter, more able students achieve more but that how students feel about science is not related to their ability/aptitude.

In What Ways Are the Outcomes of Science Learning Different For Students of Contrasting Age or Previous Experience?

When achievement outcomes were examined, most studies found that age/previous schooling experience indicators were not significantly related to dependent variables. In a sample of 34 high school students, Wormack (333) found no evidence that age was related to score on a criterion achievement test of science knowledge. Kishta (158) studied 129 tenth-grade Jordanian students and found no evidence that age and cognitive development were related. In his sample of 40 ninth and eleventh-grade students, Bady (11) was unable to detect evidence of a relationship between previous school achievement and students' logic in testing hypotheses. With 81 Saudi Arabian high school students, Mulla (217) was unsuccessful in a search for a correlation between age and teacher grades as indicators of achievement. Grant (107) examined students' solution of science problems and found that tenth, eleventh, and twelfth graders did about the same. With 86 high school chemistry students, Stephenson (282) did not find age to be related to performance on a criterion chemistry test, but did find a significant relationship between student grade-point average and achievement in chemistry. While Collins (54) did not find any evidence of a relationship between SRA achievement in science, mathematics, or reading with a criterion test in physics, Jimenex and Rosendo (140) did find, with a sample of 28 physics students in Mexico, that the chemistry background physics students had was significantly related to their achievement in physics. Contrasting tenth and eleventh-grade students in Egypt, Abdel-Wahab (2) found a significant correlation between grade level and physics achievement. National Assessment (220) data show a significant difference between student achievement in grades ten, eleven, and twelve. An interesting pattern in these results is the marked lower performance of 17 year-olds in grade ten as contrasted with 17 year-olds in grades eleven and twelve. Thus, while age itself is not a variable in these data, the grade level is. Van der Berg (311) did find, however, in his study of 66 high school and college students, that older students did better in tests of propositional thinking and analytical thinking. In an interesting study, Lybeck (187) looked at tenth-grade Swedish students' understanding of a Cartesian Diver demonstration. He found that understanding was closely associated with measures of the relevant school experiences of students.

Within the narrow band of age differences in the high school, age per se does not seem to be a significant contributor to achievement outcomes. But, when the nature of past experiences are considered, especially those experience indicators that are closely related to the instructional context, certain past experience indicators of students are useful predictors of achievement in science.

While the relationship between past experience and achievement may have a substantial base, a similar relationship between experience and attitudinal outcomes is not as clear. In a study with 143 tenth and twelfth graders, Kuhn (167) found no evidence of a relationship between student age, grade completed, or number of high school science courses and interest in energy-related topics.

Quint (246) found that student age did not seem to relate to the impact on parent attitudes. With a sample of 122 high school biology students, Kudlas (166) found no evidence that age was related to attitude changes.

These studies may be indicators that attitudinal outcomes at the high school level are relatively stable and not subject to the age-related fluctuations observed in younger students.

At the secondary level, a student's previous experience rather than age appears to be a contributor to success in science achievement but neither age nor experience appear to be related to attitudinal outcomes.

In What Ways Are the Outcomes of Science Learning Related to the Student's Environmental Background Variables?

Of the 11 studies in which high school student's environmental background such as socio-economic or ethnic origin were considered as a variable, only four looked at the contribution of this element to achievement. National Assessment (220) reported that, in 17 year-olds, race was a significant variable in all categories: whites did better than did Hispanics who did better than blacks. Kishta (158) used a sample of 129 tenth-grade students to see if United States and Jordanian students differed in their cognitive development performance. He found United States students significantly more advanced than Jordanian, and urban more advanced than rural students in both cultures. In his study of 81 Saudi Arabian students, Mulla (217) found that urban and rural students did not achieve differently when the indicators of achievement were teachers' grades. Stitt (283) found no evidence that socio-economic status was related to achievement in chemistry.

In 1979, researchers hypothesized a relationship between this element and a variety of attitudinal outcomes. Gay (103) found more whites selected physics than blacks. In his study of students' attitudes toward socially-related science issues, Uzzo (309) found that Puerto Ricans were more conservative than were whites while blacks were the most liberal in their attitudes. Speece (277) looked at factors that appeared to influence students' decisions to participate in science fairs. She found that both teacher and parent interest in science fairs were significant factors. Quint (246) found that socio-economic status indicators and parent occupations seemed not to be related to changes in parent's attitudes toward energy conservation when their children received special instruction. Both Kudlas (166) and Stitt (283) found no evidence that socio-economic status was related to attitude changes. Tamir (291) did find that United States students tended to be more curious than were their Israeli counterparts.

The complex nature of this environmentally-oriented element makes explicit conclusions difficult. In most cases, however, ethnic and cultural backgrounds seem to produce pronounced differences in achievement or attitudinal outcomes.

In What Ways Are the Outcomes of Science Learning Related to Student Personalogical Variables?

By the time the student is in high school, many researchers expect that cognitive development may be nearing its highest level and that learning styles are established. In most of the studies reporting on these variables, the more advanced the level of cognitive development, the better the student's achievement. Wormack (333) found that of the 34 high school students in his sample, those who had higher structuring ability did better on a criterion achievement test. Using a sample of 110 Nigerian high school students, Ehindero (89) found that formal students did better than concrete students in biology achievement. Lybeck (188) found a similar relationship for physics students. Holden (126) studied 199 high school biology students and found that formal students outperformed concrete students on an achievement test in ecology. The students seemed to show no difference in their attitudes toward the environment. Cobern (49) also found formal students doing better in biology, as did Stephenson (282) in a study of chemistry achievement. However, two studies yielded contrasting results. Collins (54) studied 100 tenth and twelfth graders and found no evidence of a relationship between their cognitive development and achievement in physics. Grant (107) used a criterion test of problem solving and found that students of different cognitive development achieved similarly.

Two dimensions of learning style were reported in studies of high school students. The influence of field-independence and field-dependence was examined in two studies. Douglas (76) found that field-dependent students did better on a criterion biology test. In contrast, Holden (126) found that field-independent students achieved more ecological knowledge.

Three studies reported investigating the contrast between "internal" and "external" learning styles. Long et al. (118) found no evidence that "internals" or "externals" learned more biology. Holden (126), however, found "internals" did learn more ecology than did "externals," and that they had a more positive attitude toward their environment. Ebeling (87) also found that "internals" had a more positive attitude toward the environment than did "externals."

Knowing a student's level of cognitive development provides substantial information that helps understand a student's achievement or lack of it. Knowledge of a student's cognitive development or learning style provides little help, however, in understanding attitudinal outcomes.

At the secondary level other personalogical variables included cognitive preference, study habits, motives, self evaluation and interests, and time spent studying. Theobald (293) found that cognitive preference, i.e., openmindedness contributed significantly to achievement in biology. Dekkers (68) also found cognitive preference to be an important variable. Zvi et al. (340) found a student's cognitive preference to be related to achievement in chemistry.

Commitment of the student is another personal factor related to success in achievement. In a study of 28 Mexican high school physics students, Jimenez and Rosendo (140) found achievement to be related to time spent studying. In a study of 81 high school students in Saudi Arabia, Mulla (217) found a significant correlation between student motivation, tolerance for ambiguity, anxiety and self evaluation, and their science grades. He did not find evidence of a similar correlation between student attitude and study habits.

Stephenson (282) found no evidence that student attitude influenced chemistry achievement. Kuhn (167) found a similar lack of evidence for student attitude and interest in energy conservation. Speece (277) did find a correlation between student interest in science fairs and willingness to participate. Gay (103) also found a correlation between student interest and enrollment in physics classes.

Thus, knowing something about a student's self perception, interest, and motivation can be useful improving instruction.

Summary

Science learning is occurring in high school. Based on the 75 1979 research studies that included an element of the student filter, it would appear that boys and girls do not consistently show differences in their achievement; students with higher aptitude do better than those with lower aptitude; students with relevant previous experiences rather than mere age do better on achievement but variance in attitudinal outcomes is unrelated to age/experience; environmental variables such as home background and ethnic origin are significant contributors to outcomes of the science learning context; variations in personalogical variables such as cognitive development level, learning style, motivation, and attitudes show trends of being useful predictors of achievement.

The Teacher Filter

Within the science learning context of the high school, 13 of the 1979 research studies included an element of the teacher filter as an independent variable. In these elements indicators were how either a teacher's knowledge or pedagogical skills influences student achievement or attitudinal outcomes.

In What Ways Are the Science Learning Outcomes Influenced By A Teacher's Knowledge?

The depth of knowledge of a teacher was reflected in two studies. Spencer (278) surveyed British science teachers as to the source of scientific information they used. He found that most British science teachers depend on other teachers for their information rather than on published sources or professional organizations. Bruno (33) also noted that teachers in rural areas usually taught a wide range of courses and, by implication, had little time for adequate in-depth excellence in any single science subject area. Toews (300) found a significant correlation between the teachers' knowledge of the structure of the subject they were teaching and their students' achievement. In his study of 78 superior science students, MacCurdy (190) noted the highly important effect on students of a science teacher who was a person to imitate. However, Romano (253) reported an interesting study of 35 biology teachers and their students. He found no evidence of a relationship between teachers' performance on the National Teachers Examination and their students' gain on a different standardized achievement examination. He did find that 46 percent of the classes showed a negative gain for the year--that is, the higher the teacher's score, the less the students gained.

The precise relationship between what a teacher knows of the science content to be taught and the intended outcomes of science instruction thus has received a little attention in the research of 1979. However, it appears that student learning is influenced by teachers' knowledge. Why this silence in our research?

In What Ways Are the Science Learning Outcomes Influenced By A Teacher's Preactive and Interactive Pedagogical Skills?

Preactive pedagogical skills of high school science teachers were the foci of four research reports. The opportunity a teacher has to reflect on the methods and materials for instruction seems to be the most frequent concern. Welch (325) reported that teachers believe they need inservice and curriculum development under federal sponsorship. In his study, the teachers' principals agreed with the priority of need, but believed it is best done at the local school district level rather than external to the local context. In contrast, Moore (216) reported that 80 percent of the science teachers in Tennessee had not participated in an inservice workshop since 1972--and that most of them were satisfied with their present program. In her needs assessment of science in Tennessee, Crockett (59) found that parents and students thought teachers needed new ideas. In the results of his survey of Nebraska science teachers, Bruno (33) showed that they were still using conventional teaching methods and materials--and were quite satisfied with them.

At the secondary level, scant attention seems to be given to providing the science teacher with fresh curriculum materials and strategies. Is this reflected in the current decline in the science performance of secondary students?

That the teacher's behavior in the classroom (interactive pedagogical skills) is a significant factor in student learning seems logical, but empirical evidence that links specific teacher behavior to student behavior or student outcomes is not easily found. Manley (194) did study the extent to which teacher behavior in the learning environment influenced students' attitudes toward chemistry. He found that the teacher's verbal behavior in interpreting key ideas in chemistry was a significant contributor to students' positive attitudes. Bollinger (25) found a significant correlation between a teacher's verbal behavior in the science classroom and student attitude toward science. He did not find evidence for a similar relationship between teachers' nonverbal behavior and student attitudinal outcomes. However, positive teachers tended to have a greater variety of instructional activities.

Ross (254) looked at how teachers and principals perceived the adequacy of the science learning environment and found that principals tended to rate it much higher than did teachers most of the time. Hassan (119) studied how students perceived the classroom environment when they had teachers who had quite different interaction control strategies. In his study of Sudanese high school students, he found no evidence of differences in how students perceived the classroom when they had a teacher who demonstrated custodial or humanistic management strategies.

Does a teacher's actions in the classroom make a difference in student achievement and attitudinal outcomes? Different groups think so, but evidence is needed to clearly support this assumption.

The Instruction Filter

A third contributor to the differences in student science achievement and attitudinal outcomes is the instructional context. Within this context, both the substance or ideas or content and the instructional strategies or methods were examined in the 1979 science education research. Some studies also dealt with the interaction of elements of the student filter or teacher filter with the instruction filter. Thus, by letting the "order of things" emerge as found in the 54 studies that examined some aspect of instruction as an independent variable, the "order of ideas" or elements are as follows (see Table 7):

what ideas,
what ideas with what students,
what ideas with what teachers,
what instructional strategies or tactics,
what curricula,
what curricula with what students.

From these studies, the evidence is rather clear that variance in student achievement can be modified by changing elements of the instruction filter.

Table 7

Summary of Number of Studies in the Instruction Filter

Element	No. of Studies
Content	
What ideas?	16
Content + Student	
What ideas with what students?	4
Content + Teacher	
What ideas with what teachers?	6
Method	
What instructional strategies or tactics?	13
Content + Method	
What curricula?	4
Content + Method + Students	
What curriculum with what students?	11
	54

In What Ways Are the Outcomes of Science Learning Influenced by the Content of That Learning?

In the 16 studies that report results related to the content or ideas that are or should be in the science learning instruction, there are four types of answers: a) what should be based on a philosophical stance, b) what should be based on analysis of current practice,.c) what should be based on patterns of curriculum development, and d) what should be based on empirical studies of the impact of specific ideas on student outcomes.

Two studies included a philosophical orientation to what should be. Munro (218) developed an argument that science instruction is educationally valuable to the extent that it is consistent with the nature of science. In Crockett's (59) Tennessee survey, she found that parents believed science should be included in the high school and that they, the parents, should be involved in curriculum development for these science courses.

In the six studies that described the current content of science, a range of questions were explored. Levin and Lindbeck (177) surveyed biology textbooks to see the extent to which they included such controversial issues as evolution, disease, drugs, environment, human genetics, human reproduction, origin of life, population explosion, radiation, race, and man in nature. They found no text that included all the issues. Skogg (274) traced the inclusion of evolution in high school textbooks. In his survey of 92 texts published from 1900 to 1977, he found little attention given to the topic prior to 1950, a high emphasis from 1950-1970, and a significant decline in emphasis since 1970.

Roy (255) presented a similar analysis of what has been emphasized in earth science concepts. Jones (143) designed a scheme for analyzing a biology text. In a survey of current practices in Nebraska, Bruno (33) found that five of the new secondary materials were being used, few advanced science courses were being offered and that there were very few efforts to update or modify the content of the science curricula.

One way to influence or update the content of science instruction is to develop new or modified curricula. Four reports describe the efforts to do this, e.g., Jasim (139) developed a chemistry course for students in Kuwait, Dienye (73) designed a population education curriculum for Nigeria, Foster (97) designed a curriculum in ecology, and Marathe (195) described a model for curriculum development.

A fourth dimension of this element of what ideas will influence student achievement and attitudinal outcomes consisted of the experimental studies to evaluate empirical evidence that specific ideas or content does make a difference. In a study with 276 students, Tamir (291) found that inquiry as a topic of study made a significant difference in students' curiosity. Gibian (105) found that instruction on a specific problem solving model produced significant achievement and attitudinal changes. Polland (243) looked at how instruction with analogies would influence achievement. In his sample of 129, one group received highly complex analogies while a second group had lower complex analogies and a third group had no analogies. Only those students who had the highly complex analogies showed differences in achievement. Bullock (35) found that including water models in physics instruction influenced students' physics achievement. But Lawson et al. (175) found that biology instruction did not produce an increase of correlational reasoning.

National surveys show that the textbook is the overwhelming powerful source of content for secondary classrooms. Students are not likely to learn ideas for which they have no instruction or experience. These studies would suggest that the content of secondary science classes is not being substantially influenced by current scientific thinking or social concerns.

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Interaction of Content and Students of Differing Characteristics?

When the content of science instruction is considered either through the eyes of high school science students or in the light of student characteristics, a valuable source of information is available to the teacher. Dekkers and Allen (68) found that student preference for specific ideas could influence school practices. Adbel-Wahab (2) found that older students achieved more than did younger ones. Taylor (292) reported evidence that physics textbooks were biased against girls. However, Unan (308) found that, given the same biology content, girls achieved more on a criterion test than did boys.

Is it possible that the same content will not fit each student equally well? If so, what student characteristics should be considered in modifying the content? This question remains unexplored in the 1979 research reports.

In What Ways Are the Outcomes of Science Learning Influenced by the Interaction of Content and Teachers of Different Characteristics?

In this element, teacher characteristics such as background knowledge, cognitive development, and teaching strategies have been examined. Toews (300) found that the teacher's knowledge of a subject-centered curriculum or a unified science curriculum was a more powerful determinant of student achievement and attitudinal outcomes than was the curriculum itself. Tighe (297) found that the teacher's major (English, science, or social science) was a significant contributor to his/her expectations for students in the use of English in written reports. In contrast, Carparelli (42) did not find evidence that a teacher's level of cognitive development (formal or concrete) was related to the cognitive level of the verbal discussion in the classroom. Lamb (171) did find that the more the teacher structured a lecture, the greater the students' achievement. Manley (194) found that a significant contributor to student achievement and attitude was the teacher's interpretation of the curriculum rather than the curriculum itself. Bollinger (25) found that a teacher's verbal behavior in the classroom and his/her personal attitude toward science had a clear impact on student attitude toward science. He found no evidence of a similar relationship between the teacher's nonverbal behavior or attitude toward teaching and student attitude.

Teachers do make a difference. Given similar instructional settings, these studies report some of the growing body of evidence that identifies specific ways teachers can enhance the outcomes of instruction.

In What Ways Are the Outcomes of Science Learning Influenced by the Instructional Strategies or Tactics?

The instructional methodology that is reported in the 1979 research tends to be either a global strategy characteristic of an instructional course or a specific tactic used in instruction for a given period of time. In 9 of the 13 studies in which instruction methodology was examined, the independent variable was a more global strategy. Raghabir (247) compared the impact of a laboratory-investigative strategy and a laboratory-lecture strategy with 54 twelfth graders. He found the laboratory-investigative strategy produced greater learning and more positive attitudes. Capie et al. (41) described how the size of the instructional group can influence the amount of on-task behavior and student achievement. Grant (107) found that students who worked in groups while solving problems did better than those who worked alone if they had had previous group problem solving experience. McGahan (203) found that small groups got more work done but did not find any evidence of differences in achievement and attitudinal outcomes when small group activities were compared with individualized instruction. In a study of 98 tenth graders, Wallace (320) found that students in individualized study were absent more and that those students in group instruction achieved more.

In addition to the group size aspect of this element, other studies looked at an inquiry mode of teaching. Marek and Renner (197) found that an inquiry teaching mode resulted in increased student achievement and advanced cognitive development. Hughes (136) found that twelfth grade students in a teacher-directed strategy did significantly better than those in a student-directed strategy. Olarinoye (226) did not find evidence of a difference in achievement between guided inquiry, an inquiry role approach, and conventional instruction but he did find that the students in the conventional instruction had a more positive perception of their achievement. In a similar outcome, Salib (258) was unable to find evidence of differences in student achievement or attitudinal outcomes when discovery and expository instruction were compared.

Knowing what aspect of these instructional strategies are important for what outcomes remains a key question that needs further study.

The studies involving tactics present a clearer picture. In his study of 62 eleventh grade biology students, Raghubir (248) found that providing students with objectives helped them achieve significantly more than those who did not have the objectives. Kahle (145) however, found that while objectives did not help students, advance organizers did. Hicks (122) studied the impact of providing physics students with graphs or mathematical formulas as a tactic to help them understand physics relationships. He found no evidence that the tactic made a difference. Ray (249) studied the impact of level of teacher questioning on 54 chemistry students. He found that the higher the questioning level, the greater the abstract reasoning and critical thinking of the students.

Clearly, the instructional strategies and tactics have been shown to correlate with increased learning. Continued study is needed to identify why or what aspects of student behavior or learning these strategies are influencing so that this positive impact can be increased.

In What Ways Are the Outcomes of Science Learning Influenced by the Combined Impact of Content and Method or the Curriculum?

A superficial question related to this element is: Does a total course make a difference? Kudlas (166) found that a high school biology course did indeed influence student attitudes. Jimenez and Rosendo (140) found a similar result in that students who had a high school physics course knew more physics and had a more positive attitude than those who had not taken the course. Looking at a specific part of a course, the impact of field trips, Ignatiuk (137) found that they seemed to influence student attitudes. However, Stitt (283) found that teaching a course through the use of toys did not seem to help the achievement or attitudes of students.

Inquiry about a total curriculum may be of limited value in helping teachers know how to enhance the outcomes of the science learning context. Knowing that curriculum "A" is better than curriculum "B" still leaves the question open--why is it better?

In What Ways Are the Outcomes of Science Learning Influenced by the Interaction of Curricula with Students of Differing Characteristics?

In these eleven studies, clear evidence for a student characteristic/treatment interaction is found--even when the treatment was a global instructional strategy. Douglass (75) compared the relative impact of an inductive/deductive teaching strategy on students of differing learning style (global or analytical). Using a sample of 627 biology students, she found that analytical students did better with an inductive strategy and that global students did better with a deductive strategy. In another study, Douglass (76) found that field dependent students did better in a deductive strategy and field independent students achieved more in an inductive strategy. While Long et al. (181), with a sample of 93, found that students in teacher-managed instruction achieved more than those in student-managed instruction, these differences did not seem to be correlated with student aptitude or preference for instructional strategy. In contrast, Theobald (293) found that dogmatic students achieved more in a group-centered instructional strategy and openminded students achieved more in a student-centered individualized strategy. Dunkum (80) found no evidence that a computer-augmented lecture produced different results than did the simple lecture. Ebeling (87) found, with a sample of 120 high school biology students, that those in the lecture-discussion treatment achieved more environmental knowledge and had a more positive attitude than those in the lecture-role playing or lecture-project treatments. He found that, regardless of the teacher, the more "external" a student was, the more positive his attitude toward the environment tended to be. With a sample of 95 high school physics students, Quint (246) compared the impact of assigned study at home with only in-school assigned study on parent attitudes toward energy conservation. He found that the in-school group had parents with the greater attitude change. Collins (54) found that the level of instruction was correlated with achievement (formal instruction with formal achievement tasks) but that those correlations seemed to be independent of student aptitude scores.

In a study of the impact of the tactic of using diagnostic tests, Brown and Butts (30) reported that, with 60 high school physiology students, no evidence was found that the use of the tests made a difference in achievement. Higher aptitude students, however, had a more positive attitude toward the tests. Jones (142) compared the impact of using advance organizers with high achieving students and with low achieving students. They helped the former but not the latter. Lueckemeyer (184) found that using the mastery learning/remediation tactic with 185 tenth graders produced significant achievement gains and that these gains appeared to be independent of student aptitude.

Based on these studies, exciting relationships between students and instruction begin to emerge. Careful and thoughtful pursuit of hypothesized relationships can help map out the complexities of instructional interactions.

Summary

In the 142 studies in which the science learning outcomes of the adolescent were studied, variations in these outcomes were found to be described in terms of the elements of these filters.

The Student Filter (n = 75 studies)

A. Gender - no consistent differences found

B. Ability/Aptitude - higher ability students do better than lower ability students

C. Previous Experience - experiences relevant to the instruction rather than just age, are related to achievement outcomes

D. Environmental Variables - ethnic origin but not home background is clearly associated with achievement and attitudinal outcomes

E. Personalogical Variables - the more advanced the cognitive development of the student, the better the achievement; learning styles and other personality variables were found in too few studies to establish a pattern

The Teacher Filter (n = 13 studies)

A. Teacher Knowledge - too few studies to establish a pattern

B. Teacher Pedagogical Skills - too few studies to establish a pattern

The Instruction Filter (n = 54 studies)

A. Content - current content in secondary science is largely undisturbed by current scientific developments

B. Method - specific instructional tactics or strategies do make a difference in achievement

SEARCHING THE SCIENCE LEARNING CONTEXT OF THE UNDERGRADUATE COLLEGIAN

College is the context for the completion of the academic foundation of the student. Science knowledges, skills, and strategies are polished through extensive systematic surveys of the science disciplines.

In this section, the research studies will describe new evidence that the collegiate context is one that is undergoing a rapid transformation.

The Student Filter

In the science education research studies reported in 1979, 79 studies included elements of the collegian student filter. These elements have been categorized as gender-related variables, ability/aptitude, age/previous experience, environmental variables, and personalogical variables. In Table 8 a summary of the findings related to the collegiate student filter are given.

In What Ways Are the Outcomes of Science Learning Different for Boys Than for Girls?

Gender-related differences in achievement and attitudinal outcomes at the collegiate level were examined in 11 studies. In 9 of the 11 studies, boys' and girls' achievement and attitudes were similar. These findings seem to hold consistent for a variety of subject areas, e.g., chemistry (Andrews, 8; Petrich, 239), biology (Bailey, 12; Walker, 317), and physics (Krishnan, 163; Pridmore, 236). When MacCurdy (190) studied 78 superior science achievers, he found an equal representation of boys and girls. Killian (153) also found no evidence of a gender-related difference in cognitive development. In a study of 1,014 nonscience majors in college chemistry classes, Helms (121) found that boys and girls had similar expectations of science.

In two studies, gender-related differences were found. Vicks (314) found that males did not show significantly different achievement in biology than females, but they did score higher on career motivation. Kirkland (156) also found that males had higher achievement than did females, but that the females had a significantly more positive attitude about audio--tutorial instruction than males.

At the collegiate level, the evidence indicates that boys and girls will probably achieve about the same.

In What Ways Are the Outcomes of Science Learning Different for Students of Differing Aptitude or Ability?

This element of the student filter has been described or measured by general aptitude tests, ACT scores, SAT scores, IQ, reading ability, and mathematics/spatial reasoning tests.

Table 8

Research Studies Related to the Student Filter in the Collegiate Science Learning Context

Element	No. of Studies	Findings: Related to Achievement Outcomes ND	H > L	H < L	Findings: Related to Attitudinal Outcomes ND	H > L	H < L
Gender	11	8	2	-	1		1
Ability/Aptitude	13	4	8	-	1		-
Age/Previous Experience	24	8	15	-	1		-
Environmental	5	2	3	-	-		-
Personalogical	26	12	11	-	-		-
	79						

Most studies at the collegiate level have searched for an aptitude/achievement link although one study (Dapper, 64) did not look for evidence of such a link. Using the SAT as the aptitude measure with a sample of 304, he found no evidence that aptitude is related to attitude toward science.

In using the ACT score as the indicator of aptitude, Killian (153) found a significant correlation between it and the student's level of cognitive development. With a sample of 130, Fletcher (96) also found a significant correlation between ACT scores and achievement in chemistry. Filson (94) did not find evidence for a relationship between general aptitude and achievement in geology. Barnes (14) failed to find a predictive relationship with the verbal scores of the SAT and achievement in chemistry. However, she did find a significant correlation between the mathematics SAT score and chemistry achievement. Bailey (12) used the verbal SAT as an indicator and found it correlated significantly with critical thinking in biology. Pridmore (236) also found the SAT to correlate with achievement in physics in his sample of 117 collegian students. Andrews (8) found that mathematics SAT scores correlated with achievement, and Ozogomongan and Loptus (231) found them correlated with chemistry achievement. In his study with 303 college students, Dallam (61) did not find evidence that reading ability was associated with successful science achievement.

In two studies, student IQ was used as an indicator of ability. MacCurdy (190) found no evidence that IQ was correlated with superior science students but Cole (52) found that science achievement was significantly correlated with IQ. In his study of 196 students in computer programming, Schroeder (264) found that mathematical reasoning ability was not related to achievement.

The trend is not unexpected. College students who do well on standardized aptitude tests tend to achieve better in college science classes.

In What Ways Are the Outcomes of Science Learning Different for Students of Contrasting Age or Previous Experience?

The collegiate student's previous experience was included as an independent variable in 19 studies. In three studies, age was the indicator while in most of the studies high school or previous college performance was thought to be related to achievement outcomes. As an indicator of the element, no evidence was found that age was related to chemistry achievement (Petrich, 239), biology achievement (Vicks, 314), physics achievement (Pridmore, 236) or student expectations from science (Helms, 121).

High school grades and courses were expected to be related to college science achievement. In a study with 130 college chemistry students, Fletcher (96) found that the high school chemistry grade was a significant predictor of college chemistry achievement. A similar relationship between high school physics grades or overall high school grade point average was not found. As was the case in a study by Andrews (8), Ozsogomogan and Loptus (231) also found a significant correlation between high school chemistry grades and college chemistry achievement. In contrast, Bailey (12) found no evidence of a relationship between the number of years of high school science and achievement in college biology. Barnes (14) also found no evidence that high school mathematics courses, general grade point average, science classes, or science grades were related to achievement in chemistry. In a sample of 117 students, Pridmore (236) found that high school mathematics and general grade point average were significant predictors of college physics achievement. Kamchaturas (148) also found high school science courses to be related to college biology test results.

The mathematics skills that a student possesses have been used as an indicator of previous learning. Champagne et al. (44) found no evidence these skills were related to scucess in college physics. But Trummel (307) and Pridmore (236) both found mathematics skills to be significant predictors of success in college physics. Bardole and Bardole (13) and Barnes (14) also found mathematics skills to be a good predictor of success in college chemistry. Champagne et al. (44) did find that a student's misconceptions (acquired in earlier science courses) were a significant predictor of poor physics achievement. Ozsogomongan and Loptus (231) were able to use a chemistry pretest (also a measure of previous science learning) to predict success in college chemistry. Helms (121) found that students' nonacademic or nonscience reading interests were correlated with what they expected from science.

Previous college experiences as indicators have also been explored. General grade point average was found by Filson (94) to be a significant predictor of success in geology but number of quarters in college, college science courses, or college mathematics courses were not. Vicks (314) and Pridmore (236) also found college GPA to be a significant predictor of success in biology. Previous college biology classes did not seem to help students, in Brumby's (31) study, their understanding of biological evolution. With a sample of 298 college students, Kirkland (156) found that their academic standing as upper level or lower level was significantly related to both student science achievement and attitudes toward science. With 88 students in his sample, Hill (123) found no evidence that GPA was related to a student's ability to visualize solutions to science problems.

Based on the numerous studies reported in 1979, clearly one would expect students who have had excellent high school instruction in closely related subjects and who are doing well academically in college to achieve well in college science courses.

In What Ways Are the Outcomes of Science Learning Related to the Student's Environmental Backgrounds?

Two dimensions of the environmental background element were examined in five research studies with college students in 1979. No evidence was found in two studies that home/family variables were related to achievement in biology when these variables were estimated using size of home town or type of high school attended (Bailey, 12) or where family size or income were used Vicks, 314).

On the other hand, when ethnic origin or a related variable, primary language, was examined, significant relationships were found in physics achievement (Krishnan, 163), chemistry achievement (Petrich, 239), and biology achievement (Noble et al., 222).

These five studies underscore this potentially powerful element of the student filter. This element needs much more careful study to comprehend the meaning of this limited number of studies.

In What Ways Are the Outcomes of Science Learning Related to Student's Personalogical Variables?

Logic would seem to indicate that level of cognitive development and pattern of learning styles would be key factors that could be expected to influence student achievement and possibly attitudes toward science learning. Although this element was included in 17 studies of collegiate science performance, in 11 studies no evidence was found to support a hypothesized relationship.

Relative to cognitive development, Walker (317) studied 44 students in a genetics course and found a significant correlation between formal reasoning ability and genetics achievement tests but a similar relationship between cognitive development level and course grade was not found. With a sample of 60 students, Davis (67) looked at the relationship between students' cognitive developmental level and their achievement when the structure of the communication was the key consideration. He found that formal students did well in low structured contexts and concrete students did better in higher structured contexts. Schroeder (264) and Ward (321) both found formal students' achievement higher than concrete students. In their study of 60 college physics students, Liberman and Hudson (179) found that concrete reasoning was a significant factor in predicting failure in physics achievement.

In contrast to these studies where the cognitive developmental level of the student was useful in understanding achievement, no evidence of such a relationship was found by Dallam (61) for 303 students in a natural science course; by Champagne et al. (44) for achievement in classical mechanics; by Filson (94), with 170 students in geology; by Charoenpit (46) with 176 students in chemistry and Williams (328), with 861 science majors and nonscience majors in chemistry; by Hill (123), with 88 students in a problem-solving achievement test; or by Cole (52), in a general science achievement test.

A possible reason for these contrasting results of the influence of a student's level of cognitive development on achievement may rest in the closeness between the level of reasoning required for successful performance on the achievement measure. As illustrated in Walker et al. (318), the cognitive demand of the criterion measure may be more readily visualized in a specific test than in a general criterion measure of total course grade.

Learning styles have been described as the "internal/external" dimension of students' preferences, their "field-dependence," their factual versus conceptual preference for course organization or a general cognitive style as defined by Hull in Holm's (129) study. Yeany et al. (337) and Dapper (64) found no evidence of a relationship between "internal/external" preference of students and either achievement or attitudinal outcomes. Mackie (192) did find that field dependent students did better on both achievement and attitudinal outcomes than did field independent students. In a study with 121 students, DeLuca (69) found that students who were classified as factual rather than conceptual in learning preference did better on an astronomy criterion test.

Learning style illustrates an element of the student filter that needs a much more careful delineation and search before clear patterns of its influence can be described.

Other personalogical indicators included collegian's attitudes, self perception of preference, and motivation. Students' attitudes toward their institution, the subject, and teacher were found to have no significant correlation with biology achievement in a study of 208 community college students by Mitchell (211). But Kamchaturas (148) and Cole (52) both found significant correlations between student attitudes toward science and their achievement in biology classes. Students with more positive attitudes tended to achieve more.

In studies where this element was represented by self-reported perception or preference, Brush (34) found no evidence of a relationship between a student's self image and either achievement or attitudinal outcomes. Crawley (55) also found that a student's preference for a course did not seem to be related to attitudinal outcomes.

While Vicks (314) found no evidence that motivation as an independent variable was related to achievement in biology, Dallam (61) found that a measure of applied motivation--the student's study practices--was significantly related to achievement measures in the natural sciences.

The "no-difference" findings related to this element may be an indicator that these variables are more closely associated with what students do in learning science rather than the measures of the outcomes of that "doing." That possibility needs study.

Summary

Study of the collegian interaction with science learning is producing a substantial addition to our knowledge of students and learning. Based on the 73 1979 research studies that included an element of the collegian student filter, it would appear that boys and girls do equally well in science; students who do well on standardized aptitude tests tend to achieve more; students with higher achievement in related high school courses do better in college achievement; environmental variables such as home background appear not to be related to college science achievement but ethnic origin is; variations in personalogical variables such as cognitive development level, learning style, motivation, and attitudes do not appear to be related to science achievement.

The Teacher Filter

Little is reported in the 1979 science education research about collegiate science teachers. McKenna et al. (204) did find in a survey of 114 college teachers that those in small schools (less than 3,500 students) felt they were isolated from colleagues with similar scholarly interests and needed more communication. In another survey of astronomy instruction in California, Eaton (86) found that astronomy instructors at colleges and universities usually had their doctorates in astronomy or physics, while less than half of the astronomy instructors in community colleges had a degree in the field. When an instructor did have a degree in astronomy or physics, the instructional and observational facilities tended to be better; however, no similar trends in curricula or library resources were found. Is completion of graduate study a simple prerequisite for effectiveness in influencing college science outcomes? Boghai (24) studied the achievement of 310 college chemistry students in two instructional settings. He found no evidence of any differences attributed to the instructors. Martin (198) surveyed the results of 1,000 students' ranking of the effectiveness of their instructors and the students' grades as a second indicator of the instructor's effectiveness. He found no evidence of a relationship.

Thus, only a brief hint is found in these studies about how a college teacher's knowledge is, indeed, an influencing factor on student learning outcomes--and an assessment of the college teacher's pedagogical skills is an unaddressed question.

The Instruction Filter

A third powerful contributor to the collegian students' achievement and attitudinal outcomes is instruction. Fifty-eight of the 1979 research reports describe the impact of the content, methods, and their interaction within the college science learning classroom. Most of these studies dealt with the development and evaluation of courses or explicit instructional strategies. A growing number of studies also examined the relationship between instruction and student characteristics in an effort to better understand observed variations on the impact of the college science learning context on desired outcomes. Table 9 summarizes the studies in the six elements of instructional filter.

Table 9

Summary of Number of Studies in the Instruction Filter

Element	Number
Content	
What ideas	19
Content and Students	
What ideas with what students	3
Content and Teacher	0
Method	20
Content and Method	3
Content + Method + Student	13
	58

In What Ways Are the Outcomes of Science Learning Influenced by the Content of That Learning?

Although what a student can learn is largely governed by the course offerings, and most of the studies reported in the 1979 sources focused on the design, development, and evaluation of science courses for college students, some studies did attend to an analysis of the impact of specific content available for students. Kyle et al. (168) and Shymansky and Penick (270) described the contrast in student behavior in the laboratory as a function of the science discipline and level of the laboratory. Vannan (313) described the impact of including suggestology in science courses on the achievement of students. Hill (123) found that adding specific content related to spatial visualization enhanced students' problem-solving achievement.

In the development of science courses, researchers have designed many courses to accomplish a variety of objectives. In Table 10 a summary of these developmental efforts indicates that in these studies four dimensions of curricular development can be observed. In all the studies there is a description of the goals for the course. In addition, two studies illustrate how these goals can be established. Hohly (125) did an analysis of problem solving in physics, separated into six skills. He then surveyed current programs to see which skills were present and which needed to be taught--as a basis for establishing a framework. Eanes (85) surveyed college instructors to secure a consensus as to what topics and objectives should be included in an anatomy and physiology course. In addition to establishing the thrust of the courses, the reports described the specific materials that were designed to be used to help students reach the goals. A third aspect

Table 10

Collegian Science Course Development in 1979 Research Reports

Researcher	Purpose	Framework Objectives	Materials Developed	Documented/ Evaluated	Dissem- inated
Collea & Nummeral (53)	Course on Abstract Thinking	x	x	?	?
Halyard & Pridmore (116)	Natural Science Course	x	x	x	?
Knoche (160)	Practical Application Physics Course	x	x	x	?
Mollura (213)	Conceptual Based Physics Course	x	x	?	?
Gerrish (104)	Course on Air Pollution	x	x	?	?
Dunn (83)	Course in Ecology for Non-Science Majors	x	x	x	?
St. Johns (257)	Introphysics Lab	x	x	x	?
Moore (215)	CAI for Lab Experience	x	x	x	?
Meyers (208)	PSI Chemistry Course	x	x	x	?
Lorenzo-O'Neill (182)	Biology Lab for Bilingual Students	x	x	x	?
Kales (147)	Modular Chemistry Course	x	x	x	?
San Julian (259)	Ecology Course	x	x	x	?
Dubravcic (79)	Basic Chemistry Course	x	x	x	?

of the course development is its documentation and evaluation. In some studies, this was done by a pre-post comparison. In others, a contrast group's performance was included. The fourth aspect is the description of how the course will be shared with others. In none of the 13 development studies was this information included.

While the content of college instruction is an essential and well documented focus for study, the apparent isolation of these development efforts and a resultant duplication of efforts are a real concern.

In What Ways Are the Outcomes of the Science Learning Context Influenced by the Interaction of Content and Students with Differing Characteristics?

In an interesting study with 93 students in two intact classes, Scott (265) found that student note-taking skill was positively correlated with academic achievement. Enhancement of student study skills may not have a high academic priority but it may have a substantial influence on academic success. Eisenberg (91) found that student achievement in a general science course was correlated with the interest in the content. But, Haley (114) found no evidence that student involvement in the course was related to either achievement or attitudinal outcomes.

How students can best relate to the content of college instruction (and the extent to which that content should be modified to fit the students) is basically an unexplored domain of the science education research reported in 1979.

In What Ways Are the Outcomes of Science Learning Influenced by the Interaction of Content and the Teacher?

In the 1979 reports of science education research, this element was not found. Is this because we expect all college teachers to be experts in all courses they teach as well as experts in how to teach them?

In What Ways Are the Outcomes of Science Learning Influenced by the Instructional Methodologies?

How teachers structure or present content continues to be a topic of high interest to researchers. Some of the studies examined a global or course strategy while others tended to look at the influence of a specific tactic on student outcomes. Studies of specific tactics included one by Beasley (17) who questioned the impact of physical or mental practice on psychomotor skills as enabling factors in chemistry achievement. In his sample of 400 students, he found either type of practice or their combination resulted in significant achievement differences when compared with the control group. With 103 students, Blum (22) found that the use of a structured game situation helped them overcome lack of essential knowledge. In a study of 15 deaf college students Braverman et al. (28) found that using visual rather than verbal clues helped these students acquire information on the human circulatory system.

In examining the impact of visual clues, Montgomery (214) found that photographs, rather than shaded diagrams or outline drawings, helped the achievement of college biology students. Kennedy (150) contrasted teaching anatomy and physiology with videotapes and conventional laboratories with no instruction. While he found that the treatment groups did better than the control, no evidence of a difference between simulated videotape experiences and hands-on laboratory instruction were found. Stout (286) studied the use of demonstration models in a stereochemical unit in organic chemistry and found that it helped increase achievement. Noble et al. (222) compared the effects of using a slide/tape or cine-loop presentation of a microbiology laboratory skill and found no evidence of a difference on the impact.

Wiseman (330) reported on the usefulness of a discussion period after a demonstration of aspects of kinetic molecular theory. He found that achievement was increased for 50 percent of students tested after the demonstration to 90 percent for students tested after the demonstration and discussion period. Yeany et al. (336) also described the impact of a modified instructional procedure. With 95 college biology students, they found that those who had performance objectives, diagnostic tests, and timely feedback did significantly better on both achievement and attitudinal outcomes than those who had performance objectives only. Mattox (199) found that providing students with either performance objectives or topic overviews seemed to influence their achievement.

Thus, the studies involving instructional tactics seem to present a positive collection of empirical evidence that sources of information for the students and the organization of that information are powerful influences on the collegian's achievement and attitudinal outcomes--even when specific characteristics of the students or teachers are not considered as variables in the study.

The studies in which instructional strategies were the key independent variables seem to fall in two groups--those that examined an aspect of information source for students, expository lectures or direct experience laboratories and those in which the control of the information pace was a factor, i.e., student control or teacher control.

In a study with 500 college students, Saunders and Dickinson (261) compared the achievement and attitudinal outcomes of students who had a lecture-laboratory strategy with those who had lecture-discussion. They found that while both groups made significant gains, there was no evidence of a difference between treatments. McLeod (205) compared the achievement and attitudinal outcomes of 105 physics students when they were in lecture-laboratory or lecture only treatment and found no evidence of a difference in the outcomes of these two groups. Paulsen (235) contrasted lecture-laboratory with lecture only and a lecture with delayed laboratory. Those students who had the laboratory did significantly better on their achievement. Williams (327) contrasted presenting a problem and procedure before lecture with the conventional pattern of lecture followed by the laboratory. He found that the experimental treatment students did significantly better on both achievement and attitudinal outcome measures of genetics. Bodine (23) used a case-study approach as a guided discovery for a treatment group and compared the outcomes with a conventional biochemistry class. She found significant differences in student attitudinal outcomes in four of the treatments but no differences in final grades.

The pattern in these studies suggests that when students and content and teachers are not isolated as some of the variables expected to influence outcomes, most students benefit from having access to both expository and hands-on sources of information.

The extent to which the student is in control or managing the pace of information is another topic researched. Schlenker (262) inquired into the impact of AT chemistry and found that students did not appear to be interested in acting in the role of pace managers. When Gillespie (106) compared AT biology with conventional lecture-laboratory courses, he found that student-managed instruction yielded higher achievement (more C's and fewer D and F grades) than did teacher-managed instruction, but no evidence of a difference in drop-out rate was found. Kirkland (156) found positive correlations between AT instruction and achievement in genetics in a self-paced course but not in conventional lecture courses. Cise (48) reported that in a student-paced PSI physics course achievement was significantly higher than in a contrasting instructor-paced course. Ozsogomonyan (231) also found that student pacing of instruction in chemistry was superior to teacher-managed instruction.

With the several studies as a basis, the importance of students pacing their information flow seems to be a greater influence in their achievement than their source of information. Maybe making the student active in the decision-making process of when to learn really results in more actual learning time--which is reflected in higher achievement. Study of the relationship between learning time and outcomes needs to be initiated in order to ascertain if the impact is really the strategy or a resultant increased learning time.

In What Ways Are the Outcomes of Science Learning Influenced by the Interaction of Content and Methodologies?

Global descriptions of the impact of the total curriculum at the college level were less frequently reported in the 1979 studies than at other levels. Trowbridge (306) did describe the results of interviews with 300 physics students and their reflection on the impact their total programs had had in helping them to understand physics. Hamelink (117) described contrasting impacts of total instructional sequence in laboratory courses in engineering and Kinsey (155) found that a course designed to have an impact on environmental knowledge and attitude was successful in influencing the knowledge of 141 students but not their attitudes.

Research studies on the impact of total curricula at the college level may be of interest to some decision makers, but the practical usefulness of research for the instructor may be so limited that few are attempting studies of this element.

In What Ways Are the Outcomes of Science Learning Influenced by the Interactions of Content and Method with Students with Differing Characteristics?

Consideration of the impact of instructional tactics with students of contrasting characteristics was found in four research reports. Lucas (185) found that when all students' achievement was considered, using advance organizers did not seem to influence achievement, but, when student cognitive structure was matched with the type of advance organizer used, significant differences were found. Students who function at a factual level did better with factually designed advance organizers and students who functioned at a conceptual level did better with conceptually-oriented advance organizers. Davis (67) found that formal students did better with low complexity problem-solving tasks while concrete students had difficulty with all problem-solving tasks. Bailey (12) found, using a model of problem solving as a tactic, that the student's high school experience and aptitude showed significant interactions with the achievement variables. The teacher was much more effective with students who had had a better background and had higher aptitudes. Petrich (239) examined the impact of specially prepared material to augment lectures and found that while general results showed little difference, consideration of the ethnic background of the student showed significant differences. Some students seemed to be actually hindered by too much organized information about the lecture.

When more global instructional strategies are considered, Yeany et al. (337) found that the learning style of the student "internal/external" did not seem to help explain the significant differences they found in achievement between a diagnostic/remediation strategy and using objectives only. Filson (94) reported that students of higher process achievement had better attitudes in geology classes taught by either expository or guided inquiry but that no evidence was found that either the treatment or treatment plus student characteristics analyses showed differences in achievement. Charoenpit (46) found that an inquiry strategy resulted in significant differences in college chemistry achievement by 176 freshmen but that student cognitive development was not a useful predictor of success. Mackie (192) studied the usefulness of providing college biology students with behavioral objectives (they were useful), especially when the learning style (field dependent or independent) was considered. She found that, with a sample of 316 biology students, the field-dependent students had better attitudes toward the instructor, but there was no evidence of a learning style/achievement relationship. Boghai (24) found that laboratory before lecture was more effective than laboratory after discussion with chemistry students of low aptitude. With the higher aptitude students, the treatment strategy appeared to make little difference.

Ward (321) experimented with a specially designed laboratory and found that, while the treatment seemed to produce no difference in achievement, a treatment by cognitive development variable did. Formal students did better in his laboratory sequence. Cole (52) also found that students with higher aptitudes and more positive attitudes did better in modular instruction than did students of lower aptitudes or less positive attitudes.

When Vicks (314) compared the relative effectiveness of a PSI course in college biology with student characteristics, she found that student aptitude was a significant factor in explaining success. Trummel (307) found that the mathematics background of the student was a significant predictor of success when student-related discussion was controlled with teacher interaction discussion in physics class. The treatments were most helpful for students with weaker backgrounds.

Summary

In the 141 studies in which the science learning outcomes of the undergraduate collegian were studied, variations in these outcomes were found to be described in terms of the element of these filters.

The Student Filter (n = 79 studies)

A. Gender - no consistent differences found

B. Ability/Aptitude - higher aptitude students do better than lower aptitude students

C. Previous Experience - excellence in high school experience clearly is related to success in college achievement

D. Environmental Variables - ethnic origin may be related to achievement but too few studies were reported to show a clear pattern

E. Personalogical Variables - no consistent difference found

The Teacher Filter (n = 4 studies)

A. Teacher Knowledge - too few studies to establish a pattern

B. Teacher Pedagogical Skills - too few studies to establish a pattern

The Instruction Filter (n = 58 studies)

A. Content - content of instruction is clearly related to specific achievement outcomes

B. Method - expository and hands-on strategies are both effective

SEARCHING THE CONTEXT OF THE SCIENCE TEACHER

A somewhat unique context of interest to researchers in science education goes beyond the usual K-12 and collegiate contexts to those learning experiences in which the preservice and inservice teacher is the learner. In this context, a number of studies were reported in 1979 in which the teacher was the student and explicit achievement and attitudinal outcomes were expected. How this "acquisition phase" of teacher education is related to the science classroom or "application phase" is reported elsewhere. In this section, the research studies will describe the 1979 evidence that the science teacher's pedagogical development is a significant topic of science education research interest.

The Student Filter

In the science education research studies reported in 1979, 33 studies included elements of the student filter. The students in these studies may have been the preservice teachers whose experience in the classroom was primarily that of informal experience or of some form of field-based instruction. In some of the studies, the student was an inservice teacher with quite a range of teaching experience. Studies in this element were grouped into the categories of gender, ability/aptitude, age and previous experience, environmental variables, and personalogical.

In What Ways Are the Outcomes of Science Teaching Pedagogy Different for Men Than for Women?

In four studies, the outcomes of pedagogical instruction compared men with women. In only one study was evidence of a significant relationship found. Marcum (196) found that women learned more aerospace information than did men, but their willingness to use that information was similar to men. In contrast, Ehrlich (90) did not find evidence of a gender-related difference in achievement of knowledge related to energy conservation. Halverson (115), MacMillan (191), and Ehrlich (90) also found no evidence of gender-related differences in attitudinal outcomes.

In this limited number of studies, gender does not appear to be a variable of importance. In the one case of difference it may have been a function of lack of previous experience or a measure of lack of knowledge that resulted in the significant difference.

In What Ways Are the Outcomes of Science Teaching Pedagogy Different for Students of Differing Aptitude or Ability?

No studies were found in the 1979 reports of research in which aptitude or ability measures were included. Is this because of the expected homogeneity of the preservice or inservice teacher population?

Table 11

Research Studies Related to the Student Filter in the Science Teacher's Pedagogical Development Context

Element	No. of Studies	Findings Related to Achievement Outcomes			Findings Related to Attitudinal Outcomes		
		ND	A > B	A < B	ND	A > B	A < B
Gender	5	-	-	1	4	-	-
Ability/Aptitude	-	-	-	-	-	-	-
Age/Previous Experience	18	-	2	-	11	3	2
Environmental Variables	5	-	1	-	4	-	-
Personalogical	5	-	2	-	2	1	-
	33						

Have the usual screening procedures resulted in a de-facto reduction in the variance of this element of the student filter to the extent that a study of this element is of little interest? Or are researchers afraid that the distribution of ability levels that would be found would be too low and thus worrisome?

In What Ways Are the Outcomes of Science Teaching Pedagogy Different for Students of Different Age or Previous Experience?

In addition to a teacher's age and previous science courses, an indicator of this element has frequently been the number of years of teaching experience. As an indicator, a preservice or inservice teacher's age has been reported an independent variable in three studies. Cunningham and Blankenship (60) studied 96 preservice teachers and found age to be a significant predictor of the maturity level of concerns they had about teaching science. With a sample of 138 inservice teachers, Halverson (115), however, did not find evidence of a relationship between age and attitudinal outcomes. Krustchinsky (165) found similar results in his study of 154 preservice teachers.

A second indicator of previous experience is the collegiate background of the students. Tolman and Barufaldi (301) found no evidence of a relationship between college science hours and experienced teachers' attitudes toward science. Riley (251) found similar results in a study with 90 preservice teachers. He did find, however, a significant positive correlation between the preservice students and their achievement in understanding science and in performance of process skills. Halverson (115) found a significant but negative correlation between inservice teachers' college science backgrounds and their attitudes toward science. Krustchinsky (165) found no evidence of a relationship between college grade point average or number of hours of science or mathematics and attitudinal outcomes. MacMillan (191), Weaver et al. (324), and Gates (102) also found no evidence of relationship between college experience, grades or courses and attitudes toward science or science teaching.

A third indicator of the previous experience element is the preservice or inservice teachers' prior knowledge as assessed in pretests. Shaffer (266) studied 57 preservice teachers and found that their level of moral reasoning as an outcome measure was significantly associated with their pre-measured moral stage. In a sample of 138 inservice teachers, Halverson (115) found a significant correlation between the teachers' pretested knowledge of Science Improvement Curriculum Study and their attitudinal outcome changes.

The fourth, and more frequently used, indicator of this element is the teacher's years of teaching experience. Cunningham and Blankenship (60) found that years of teaching experience was correlated with maturity of concern inservice teachers had about science teaching. Tolman and Barufaldi (301), however, found no evidence of a relationship between teaching experience and attitudes toward science. Strickland and Staver (287) studied 410 preservice and inservice teachers and found a negative correlation between both achievement and attitudinal outcomes. Those with less experience gained more knowledge about ecology and changed their attitudes the most. In contrast, Halverson (115) found that the more teaching experience, the greater the attitude change. In three other studies (Gates, 102; Marcum, 196; Ehrlich, 90) no evidence of relationship was found between either knowledge or skill gained or attitude change and number of years teaching experience.

In retrospect, this element may be an important one for some specific outcomes, but the general pattern suggests that age or past experience need not be considered a limiting factor in enhancing the pedagogical skills of science teachers.

In What Ways Are the Outcomes of Science Teaching Pedagogy Related to the Teacher's Socio-Economic Environment and Ethnic Background?

In addition to conventional indicators of aspects of the environmental element of the science teacher--race and geographical location, the grade level that a teacher teaches is included as an environmental factor thought to influence achievement or attitudinal outcomes. MacMillan (191) reported the only study in which the teacher's race was an independent variable. He found no evidence of a racial difference in either self concept or change in dogmatism in a study of preservice teachers. Strickland and Staver (287) compared Indiana and Florida teachers' ecological knowledge and attitudes toward ecology. They found Indiana teachers surpassed Florida teachers on both outcome measures. Why this was true represents an unanswered question. Grade level taught was reported in three studies (Cunningham and Blankenship, 60; Tolman and Barufaldi, 301; and Halverson, 115). In all three, no evidence was found to support the hypothesis that grade level is a useful predictor of attitudinal outcomes. However, Cunningham and Blankenship (60) found that the subject a teacher teaches was not related to the maturity of their concern about teaching. The more competent or comfortable teachers are with a subject, e.g., reading, the more mature are their general concerns about teaching.

Thus, it appears that environmental factors in general are not productive predictors of success of limits to achievement in pedagogical development.

In What Ways Are the Outcomes of Science Teaching Pedagogy Related to the Teachers' Personalogical Variables?

Two studies were found that explored aspects of this element. Shaffer (266) studied 56 preservice science teachers and found that those who were at the formal thinking level of cognitive development achieved a higher level of moral reasoning. He found, however, that the learning style (internal or external) did not seem to show a similar pattern. In a sample of 139 preservice teachers, Price (244) also found no evidence that students' learning styles (internal or external) were related to their perception of what they thought should be the role of a science teacher.

In the three studies that included this element, it was indicated by self concept, attitudes, or dogmatism. Shaffer (266) found a preservice teacher's self concept and attitude significantly related to achievement. The precise usefulness of the indicator of openmindedness as contrasted with closed-mindedness or dogmatism is unclear. Weaver et al. (324) found that the more intelligent, assertive, and imaginative teachers were, as measured by a dogmatism scale, the more positive their attitudes toward science. Price (244) found that dogmatism seemed not to be related to the science teacher role as perceived by preservice teachers.

How personalogical variables influence the outcome of pedagogy is an area that remains largely unexplored.

Summary

Elements of the student filter that appear to influence teachers' acquisition of knowledge and skills in science teaching were reported in 33 studies. In these studies, men appear to do as well as women; age or past experience is not a useful predictor, neither is an environmental factor. Abilities/aptitudes and personalogical variables were not studied.

The Teacher Filter

Science teachers are the students of science teacher educators. The research of 1979 is quite quiet about the influence of these educators on outcomes. Willson and Horn (329) did report that teacher educators were much more idealistic about what could and should happen in the science classroom than were high school science teachers. They viewed science in a less practical sense than did teachers. In a survey by Owens (230), a similar result was found--a much more idealistic view was held by science teacher educators than by high school science teachers in his Texas sample. Price (244) reported an interesting study in which he found the preservice teacher's perception of the role of a science teacher to be significantly influenced by the teacher educator's perception of that role.

We have very scant evidence on which to base inferences about what knowledges and skills teacher educators need to be successful in working with science teacher development.

The Instruction Filter

The study of ways in which science teachers can improve their pedagogical skills continues to be a high interest area reflected in the 1979 research reports. As summarized in Table 12, these 32 studies were mostly directed toward identifying the impact of either specific content or more global curricula for pedagogical outcomes, with some attention to how elements of the instructional filter may be interacting with the student filter.

Table 12

Summary of Studies of the Instruction Filter

Elements	No. of Studies
Content	
What ideas?	10
Content + Student	
What ideas with what students?	1
Content + Teacher	
What ideas with what teachers?	1
Methods	
What instructional strategies	3
Content + Method	
What curricula?	10
Content + Method + Student	
What curricula with what students?	7
	32

In What Ways Are the Outcomes of Science Pedagogy Influenced by the Content of Instruction?

While most of the studies relating to the content of the pedagogical instructional filter related to evidence that specific knowledge or pedagogical skill could be successfully acquired, one study reported what high school biology teachers thought should be taught to prospective science teachers. James and Stallings (138) reported a survey of 200 science teachers in which they described what they believed teachers needed to know in order to introduce laboratory exercises, care for and use the terrarium and aquarium, construct biological models, procure and use low budget equipment, maintain laboratory facilities, construct homemade equipment, and to be familiar with the local flora and fauna. It would be interesting if there were more studies of this nature to provide a pool of practitioner-generated goals with which program content could be contrasted. This goal delineation is a first step in a model for developing an unusual program as described by Butler (38). Other studies were an examination of specific teaching skills. These are summarized in Table 13. Being able to provide empirical evidence that a specific aspect of pedagogy can be

Table 13

Summary of Studies on Content of Pedagogy

Investigator	Population	Skill
Crawley & Krockover (56)	Secondary Preservice	Use of higher and lower order questions.
Wright (334)	Elementary Preservice	Using cues to help solve problems.
Dreyfus & Cohen (78)	Secondary Preservice	Using an observation scheme to understand classroom student behavior.
Lamb et al. (171)	Secondary Preservice	Using higher kinetic students in lectures.
Crawley & Krockover (57)	Secondary Preservice	Distinguishing negative from positive student classroom behavior.
Bowden (26)	Elementary Preservice	Using an observation scheme to understand classroom student behavior.
Lewis (178)	Secondary Inservice	Using student feedback and self analysis to change teaching behavior.
Symington (290)	Elementary Preservice	Ways to present problems to students.

acquired is an important first step. Being able to show that it should be acquired because it facilitates productive student behavior or outcomes is a second question unaddressed in the science education research reports of 1979.

In What Ways Are the Outcomes of the Pedagogical Science Learning Content Influenced byan Interaction Between Content and Student Differences?

In the one study related to this element, Campbell (40) studied 40 preservice and inservice elementary teachers' reading comprehension to see if instruction in process skills would influence their performance. He found that, while instruction did make a difference, no evidence was found that the amount of teaching experience was related to the achievement outcome.

In What Ways Are the Outcomes of the Pedagogical Science Learning Content Influenced by an Interaction Between Content and Teacher Characteristics?

In the one study related to this element in the 1979 reports, Price (244) studied 232 preservice elementary teachers' perceptions of what was the appropriate role of science in the classroom. While he found that this role was significantly different for field-based versus non-field based methods instruction, he also found that the methods course instructor was a significant contributor. Intuitively, we believe that what instructors value will influence their teaching. How powerful this influence is remains an area of challenging research.

In What Ways Are the Outcomes of the Pedagogical Science Learning Context Influenced by the Instructional Strategies?

In the three studies of aspects of this filter, investigators were attempting to show that an instructional strategy could produce a desired outcome. Bluhm (21) used a sample of 54 preservice elementary teachers and found that a hands-on instructional strategy was more effective than was an expository strategy in helping students acquire and use process skills. Horak (130) contrasted field-based experience in open and self contained classes with on-campus experience only and found that each was effective for different objectives. DeTure (72), in a study with 42 preservice elementary teachers, found that, through video and audio modeling, teachers can acquire better wait-time performance.

Although the studies of this element are few in number, they do show evidence that how teachers have the opportunity to learn new skills can indeed be an important factor in their acquisition of those skills. To what extent is the method used in acquisition also an important factor in the teacher's application of those skills?

In What Ways Are the Outcomes of the Pedagogical Science Learning Context Influenced by the Combined Content and Methods — or Curriculum?

In the ten studies related to this element, researchers reported on the cumulative impact of a course or a workshop on specific teacher achievement or attitudinal outcomes. Koballa and Coble (161) found that when professionally relevant activities were included in a biology course, preservice teachers' attitudes were more positive. Krammer (162) also found that the inclusion of activities in a biology course resulted in improved attitudes toward science teaching. Piper and Hough (241) found preservice teachers' attitudes after a methods course were significantly different from the attitudes of those who had not taken the course. Dunn (84) studied 59 preservice elementary teachers and found that the methods course helped them to use problem-solving strategies.

When inservice workshops were evaluated, Shrigley et al. (268) found that teachers had more positive attitudes toward science and their role; Spooner and Simpson (272) found teachers had more positive attitudes toward teaching science. Myer (219) found that the teacher took more time for the subject (environmental education) and scheduled more field trips; Dalton (62) found teachers made greater use of the curriculum materials (energy education) and valued them more; and Gabel and Rubba (101) found no evidence of attitude or performance differences.

In Gabel and Rubba (101) and O'Sullivan's (229) studies there is a somewhat unique aspect. The outcomes they looked for were more than activities and attitudinal changes. O'Sullivan found that teachers knew more but also used the skills in their classroom. These studies show that courses and workshop participation are reflected in acquisition outcomes. More research is needed to show if these outcomes are related to what teachers do in the classroom, to what their students do, and to what their students learn.

In What Ways Are the Outcomes of the Pedagogical Science Learning Context Influenced by the Interaction of Content, Method and Student Characteristics?

The seven studies in this element differ from the curriculum element mainly in their added dimension of asking with what kinds of students are courses or workshops effective. While Weaver et al. (324) did not find evidence that field experience influenced achievement and attitudinal outcomes but when personality factors were considered, a different effect was observed. The more dogmatic preservice teachers were, the greater their benefit from field experiences. Krustchinsky (165) did not find similar evidence in his analysis of student characteristics on the impact of field experience with preservice teachers. In his sample of preservice teachers, MacMillan (191) found that the course itself was a factor in influencing change in their self concept and dogmatism scores. Shaffer (266) determined that knowing students' cognitive levels and attitudes was essential to finding how much a course influenced their achievement. In a sample of 138, Halverson (115) found a negative relationship between teaching experience, college science background, and how much teachers gained from an inservice course. Marcum (196), however, found that a teacher's grade level was not a helpful predictor of knowledge acquisition in a workshop. Gates (102) described a model for an inservice workshop when teacher characteristics were correlated with outcomes. He found that all teachers seemed to gain equally well.

Summary

In the 68 studies in which the science learning outcomes of the context of science teacher preparation were studied, variations in these outcomes were found to be described in terms of the element of these filters.

The Student Filter (n = 33 studies)

A. Gender - no consistent differences were found

B. Ability/Aptitude - no studies were found of this element

C. Previous Experience - as indicated by courses or number of years of teaching experience does not seem to be associated with outcome variables

D. Environmental Variables - no consistent differences found

E. Personalogical Variables - too few studies to establish a pattern

The Teacher Filter (n = 3 studies)

A. Teacher Knowledge - too few studies to establish a pattern

B. Teacher Pedagogical Skills - too few studies to establish a pattern

The Instruction Filter (n = 32 studies)

A. Content - teaching skills can be acquired

B. Method - how teachers are taught is an unexplored area of science education research

MEASUREMENT INSTRUMENTS FOR RESEARCH IN SCIENCE EDUCATION

In the more than 340 research studies reported in 1979, 18 described efforts to develop or improve the measurement tools researchers need. A hypothesis that an element of a filter is related to or is influencing the outcome variables must be tested with valid and reliable instrumentation. Since most of the independent and dependent variables in science education research require indirect measurement, the instrumentation needed to conduct research in science education becomes even more critical. While other studies did include the development of an instrument as part of their procedure, the studies described in this chapter include those for which measurement development was the primary purpose of the research.

Of the 18 test development studies reported in 1979, 9 dealt with the measurement of achievement and attitudinal outcomes; 4 described measurement of elements of the student filter; and 4 focused on an emerging variable: teacher behavior in the learning context.

To provide the information that a user needs, a study describing a measurement scheme should include:

a) An operational definition of the construct to be measured;

b) A discussion of the alternative means that could be used to measure that construct;

c) A description of the test strategy used including directions for its administration;

d) The estimation of the validity of the test in measuring the construct;

e) The estimate of the reliability of the test in measuring the construct; and

f) A description of the people for whom the test would be useful.

In Table 14 the studies reviewed in the chapter are summarized as their reports reflect these six criteria.

Tests Related to Elements of the Student Filter

In four studies, instruments were described that can be used to measure the cognitive development functioning level of studies--part of the personalogical element of the student filter. DeLuca (69) used 384 elementary through high school students to establish the needed documentation of a test of combinational reasoning. He used an electronic simulator to measure the construct rather than a more conventional clinical interview technique. No report was given of the validity or reliability estimates for the test. Staver and Gabel (280)

Table 14

Summary of 1979 Research of Instrument Development

Study	What is the CONSTRUCT measured?	Are alternative measurement strategies described?	Is the test described?	Validity estimate	Reliability estimate	Is potential usefulness of test described?
A. **Student Filter**						
DeLuca (69)	combinatorial reasoning	yes	yes (ET)	no	no	yes
Staver & Gabel (280)	formal thought	yes	yes (PLOT)	convergence discrimination	internal consistency	yes
Walker, Hendrix & Mertens (319)	formal thought	yes	yes (PTL)	construct	no	no
Milakofsky & Patterson (209)	logical thought	yes	yes (IPDT)	concurrent	test/retest	yes
B. **Outcome Measures**						
1. **Achievement**						
Wolfe & Hiekkinen (331)	higher cognitive learning in chemistry	no	yes (THCLC)	construct convergence	internal consistency	yes
Alani (6)	science achievement	no	yes (ASAT)	internal consistency	split/half	no
Lang (172)	metric skill achievement	yes	yes (TOMS)	no	internal consistency	yes
Torrence, et al. (302)	science process skill achievement	yes	yes (TTSP)	no	no	no

Study	What is the CONSTRUCT measured?	Are alternative measurement strategies described?	Is the test described?	Validity estimate	Reliability estimate	Is potential usefulness of test described?
2. Attitude						
Downs (77)	student attitude toward classroom	n/a	n/a	n/a	n/a	n/a
Shrigley & Trueblood (269)	teacher attitude toward metrics	yes	yes (AS)	contact validity	no	no
C. Teaching Behavior						
DeLuca & Downs (70)	teacher behavior preference	yes	yes (ESTP)	content & predictive validity	n/a	yes
Suchareekul (288)	teacher inquiry behavior preference	n/a	yes (IPST)	content validity	Cronbach alpha	no
Fuhrman et al. (99)	student behavior in laboratory	n/a	yes (LSTAI)	n/a	n/a	n/a
Shymansky & Penick (270)	instructor & student behavior in laboratory	no	yes (SLIC)	no	no	yes
Yeany & Capie (338)	instructor & student behavior with process skills	no	yes (DPOG)	no	no	yes

designed the Piagetian Logical Operations Test (PLOT) as a multiple-choice group-administered test as an alternative to clinical interviews. They reported establishing both convergence and discriminance validity and a reliability estimate of .85 based on internal consistency. With 86 college students, Walker, Hendrix and Mertens (319) also developed a test of formal thought that included propositional and combinatorial logic and hypothetico-deductive reasoning tasks. For their Piagetian Task Instrument (PTI) they reported a construct validity but no reliability estimates were given. With a sample of 520 elementary through college-aged students, Milakofsky and Patterson (209) described another group administered test of formal thought. Their report included a description of concurrent validity for the test and a test-retest reliability of .28.

Tests Related to Outcomes of Science Learning

Four tests of achievement outcomes were found in the 1979 research reports. Wolfe and Hiekkinen (331) described a test to measure student achievement of higher cognitive learning in chemistry. They reported a construct validity estimate for the test and a reliability estimate based on test homogeniety. Alani (6) developed a test to measure the impact of an elementary science curriculum on Iraq sixth-grade students. Lang (172) designed a criterion referenced test to measure metric skill achievement for use with handicapped students. Torrence et al. (302) reported on a modified version of a process skill test that was designed to be administered via television. No validity or reliability estimates were included in the report.

Two studies reported the development of a measure of attitudinal outcomes: Downs (77), on student attitudes toward the classroom and Shrigley and Trueblood (269), on teacher attitudes toward metrics.

In four related studies, researchers explored in what ways the test's construction would influence variance observed in achievement outcomes. Friel and Johnstone (98) found that in multiple-choice questions, the placement of the distractor immediately before the key altered the difficulty of the item. Abu-Sayf (1) found that requiring students to identify both correct and incorrect responses to multiple-choice questions was significantly more difficult than just identifying the correct responses. Warren (323) determined that the form of a test--multiple-choice or essay--did not alter the student achievement but that multiple-choice tests were easier to grade. Holliday and Partridge (128) found that students did better on tests which were sequenced in difficulty from simple to hard than on tests in which the questions were randomly sequenced.

Tests Related to Teaching Behavior

In four studies, teaching behavior and teacher/student interactions were the constructs that were measured. DeLuca and Downs (70) described a strategy for measuring a teachers' preference for high teacher control or high student control of the classroom learning context. Suchareekul (288) also developed a test to measure a teacher's preference for using inquiry teaching strategies in the science classroom.

What students do in the science classroom or laboratory is in part a function of the teacher. Fuhrman et al. (99) described a way to measure the student's behavior in the laboratory. Shymansky and Penick (270) developed a scheme to analyze the teacher and student interactions in the college science laboratory. Yeany and Capie (338) designed an observational scheme to assess the teacher/student interaction related to specific process skills.

LOOKING BACK TO LOOK FORWARD

Trends in Research Designs for Finding "The Order of Things"

In 1979, the research designs by which science education researchers searched to find an "order of ideas" in the "order of things" illustrates a creative diversity. As indicated in Table 15, five of the six research strategy categories were represented in 336 of the 340 studies. In only five studies were the design descriptions so sketchy as to make their categorization not possible.

Historical and survey-type research accounted for 14 percent of the studies reported. In these studies, data from past events were recorded and interpretation made based on patterns observed in these data. Knowing what was the order of things of the past is one useful way to generate a basis for action about what can be done to nurture science teaching in the future.

Table 15

Categorization of the Research Design Used in the 1979 Reports of Science Education Research

	Number	Percentage
Describing Strategies		
1. Historical	49	14
2. Futuristic	0	
3. Naturalistic	6	2
Improving Strategies		
1. Exploratory	94	20
2. Experimental	132	39
3. Engineering	54	16
Unclassified	5	2

Although futuristic research has a potential for helping identify what is and what should be, no studies were found in the 1979 research reports that fit this category.

Naturalistic research illustrates a category of study which has high potential but infrequent usage. An indepth description of a science classroom or learning event from the perspective of many observers can help provide a rich basis of hypotheses about that event. Six studies, or 2 percent of the 1979 research reports, were naturalistic studies.

In the 94 studies that illustrate exploratory research, three research designs were used for data collection. In 66 studies, a posttest only design was used, i.e., data were collected from a given sample at a given point of time and then correlations obtained between the observations and specific student or teacher filter variables. In these studies the basic question was "Are student or teacher variables correlated with outcome variables?" In 16 of the exploratory studies a posttest data collection followed a specific instructional treatment, making the question thereby, "Are student or teacher variables correlated with outcome variables when they have a specific instructional program?" No control groups or random selection of students are found in studies of this group nor in the 13 studies where a pretest was added to the design. In the 13 pre-post test designed studies, the research question was "Are student or teacher variables correlated with changes in outcome variables when they have had a specific instructional program?" From these 94 studies, researchers searched to find an "order of things" on which to hypothesize an "order of ideas."

In 132 experimental studies, or 39 percent of those reported in 1979, a variety of designs were used by researchers in the attempt to verify an hypothesized "order of ideas." Figure 4 illustrates the key differences in these designs--the strategy of selecting subjects (random vs. nonrandom) and the use of control groups. The strength of the conclusions--the "order of ideas"--that come from these 132 studies fit the extent to which the design lends credibility to the outcomes and generalizability to the findings. While many studies did use intact classes or nonrandom selection of subjects, the pronounced reliance on control groups does strengthen the generalizabilities that are described.

Engineering studies include those that described the development of a curruculum, a course, a test or an instructional module. In the 54 studies in this category, substantial attention was given to the clear description of the goals of the product and the means for achieving those goals as well as some documentation of how well learners did when provided with instruction based on the product. A dimension that is needed is attention to the task of dissemination of these products (especially at the college level). In the 1979 reports, the isolated fragmentation of efforts may well encourage duplication of the same curriculum development efforts. Sustained efforts in dealing with the question "Who should know about this product?" will help link the producer and the consumer of these important research products.

While the obvious emphasis in the 1979 research reports was on exploratory and experimental research (67 percent), the results make a sobering observation necessary. We know a little more about the "order of ideas" based on our search in the "order of things." Could we learn more if we were to spend a higher amount of our time in describing what is--a higher risk research--rather than in our current emphasis in attempting to show what elements causes what outcomes and then finding that no differences are observable? Do we need to invest more effort in finding the "order of things" rather than attempting to prove that our "order of ideas" is indeed correct? In our search, are we attempting to make the "order of things" fit our "order of ideas" and the "no significant differences" are a message that communicates that our "order of ideas" do not fit the real world "order of things?"

		Selection of Subjects	
		Random	Nonrandom
Pre/Posttest	Control Group	34	42
	No Control Group	0	2
Posttest Only	Control Group	25	24
	No Control Group	0	2
Soloman 4-Square		2	1

Figure 4. Categorization of experimental research studies.

Trends in the "Order of Ideas" Based on the "Order of Things"

After an intensive examination of the "order of things" depicted in the science education research reported in 1979, an "order of ideas" emerges. Generalizing from the studies related to the learning context of the elementary school student, the emerging adolescent of the middle/junior high school, the adolescent of the high school, the collegian in undergraduate science classes, and the teacher, an "order of ideas" evolves about variables that have a potential for influencing achievement and attitudinal outcomes. The challenge now remains for this order of ideas to be subsumed, the relevant cues perceived, and appropriate responses made.

Based on one primary source of cues, the student filter, Table 16 illustrates the extensive attention this filter has received. The order of ideas that this search describes is that boys do about as well as girls at all levels. Consistently, students with higher ability or aptitude do better than their peers of lesser endowment. Initially, previous experience serves to make little difference in achievement or attitudinal outcomes but, as the student progresses in school, there appears to be a cumulative impact of experience on schooling outcomes. While many environmental variables have been briefly examined, ethnic origin is the one that consistently shows to be a significant contributor to achievement. In every study in which this variable was examined, white students do better than Hispanic students, and both of these groups do better than blacks. The personalogical variables are a mixed

Table 16

Summary of Hypothesized Relationships of the Student Filter with Achievement and Attitudinal Outcomes

Element	Total	Elementary	Junior High	Senior High	College	Teacher Education
Gender	60	11	16	17	11	5
Ability/Aptitude	51	16	12	10	13	0
Previous Experience	80	9	13	16	24	18
Environmental	31	4	6	11	5	5
Personalogical	74	5	17	21	26	5
	296	45		75	79	33

scene, probably due to the few studies in which the same variable was included. A student's cognitive developmental level does appear to be a significant predictor of academic success in studies where there is a clear parallel between the cognitive level expected in the achievement outcomes. Learning style, e.g., "internal/external," "field dependent/independent," "dogmatic/open mindedness" was briefly explored in a few studies--but too few to establish a meaningful pattern.

With the examination of elements of the student filter in no fewer than 296 hypothesized "order of things" in the 1979 research reports, why are so few definite conclusions or statements of the order of ideas possible? Could it be that the impact of element of the student filter is to be more clearly seen in interaction of students and teachers in the instructional context? Should we turn to these interactions to ascertain what student characteristics seem to be related to what goes on in the classroom? If we had a set of "order of ideas" about this aspect of learning, we could have a basis for describing how teachers could match classroom interactions with students to enhance their learning time--and ultimately, their achievement and attitudinal outcomes.

A second source of primary cues is the teacher filter. Table 17 illustrates the lack of attention this filter has received in the 1979' "order of things." In contrast to more than 296 hypothesized relationships between student characteristics and science learning context outcomes, there were less than 40 hypothesized relationships between the teacher's knowledge or pedagogical skills and achievement outcomes. While other research underscores the importance of teachers in their role in the learning contexts--this has been an area of remarkable silence in 1979's science education research. Our order of ideas about what teachers need to know about their subject and about teaching remains a challenge to be explored.

A third source of primary cues is the instruction filter. Table 18 illustrates the extensive attention this filter has received, nearly the same as the student filter. Based on the order of things observed, the order of ideas emerges. The heaviest attention has been given to the selection and design of curriculum, especially at the college level. Curriculum development has usually been based on an analyses of what is needed as defined by the developer. A few studies did include a needs assessment to secure a consensus of what a wider sample of opinions described as the ought-to-be-included ideas. In only a limited number of studies were student's interests in the context (13 of 210) even considered. The 1979 research "order of ideas" would seem to indicate that concern for the interaction of science content and student interests is either of little importance or little interest to science education researchers. All students are expected to be equally interested in all content at all times. Based on only 8 of 210 hypothesized relationships, a similar statement relative to teacher competence is also true. All teachers are expected to be equally competent with all science content at all times. Does the quietness of the 1979 "order of things" observed indicate that this is the science educators' assumed "order of ideas"--or should this assumption be challenged?

Table 17

Summary of Hypothesized Relationships of the Teacher Filter and Achievement/ Attitudinal Outcomes

Element	Total	Elementary	Junior High	Senior High	College	Teacher Education
Teacher Knowledge	20	5	3	5	4	3
Preactive and Interactive Teaching Skills	14	6	0	8	0	0
	34	11	3	13	4	3

Table 18

Summary of the Hypothesized Relationships of the Instruction Filter and Achievement/Attitudinal Outcomes

Element	Total	Elementary	Junior High	Senior High	College	Teacher Education
Content--What ideas--	62	11	6	16	19	10
a. What ideas with what students	13	4	1	4	3	1
b. What ideas with what teachers	8	1	0	6	0	1
Method--What strategies--	49	9	4	13	20	3
a. What content with what method	27	8	2	4	3	10
b. What content with what method with what students	51	11	9	11	13	7
	210	44	22	54	58	32

When method or instructional strategies and tactics are examined, the "order of things" observed strongly suggests that the "order of ideas" can be more precisely established where specific tactics are related to outcomes rather than in the case of more global courses or course methodology studies. Unexplored in these studies is a key question about how specific instructional strategies can enhance what a student does while in the classroom. It is in this domain that the greatest and possibly most exciting research potential exists.

Establishing an "order of ideas" from observed "order of things" is a challenge, for in it we can describe ways teachers can enhance student learning time which in turn will increase student achievement and attitudinal outcomes.

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